56

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WIND TUNNEL TESTS OF
NATURAL SHAPE BALLOON MODEL

Paul A. Sherburne

Goodyear Aerospace Corporation
Akron, Ohio 44315

Contract No. F19628-67-C-0145

Project No. 8680

Scientific Report No. 1

9 March 1968

Contract Monitors: Lewis Grass
Edward Young, Captain, USAF
Aerospace Instrumentation Laboratory

This research was supported by the Advanced Research Projects Agency
under ARPA Order No. 755.

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AIR FORCE CAMBRIDGE RESEARCH LABORATORIES
OFFICE OF AEROSPACE RESEARCH
UNITED STATES AIR FORCE
BEDFORD, MASSACHUSETTS 01730

46

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ABSTRACT

To further the development of high-altitude tethered balloons, wind tunnel testing of a rigid model of a natural shape balloon was performed at Ames Aeronautical Laboratory of NASA. The rigid model tested represented a shape with top loading $F/p = 0$, superpressure parameter $\alpha = 0.9315$, and $\Sigma = 0.0315$. Aerodynamic data obtained in the Ames 12-foot pressure tunnel include lift, drag, pitching moment, and surface pressure distribution for the Reynolds number range of 450,000 to 12 million. Examination of the data, reduced by NASA, indicates that (1) stall occurs at a positive angle of attack less than 10 degrees, (2) an aerodynamic unstable trim point occurs between 5 and 15 degrees angle of attack, and (3) the drag at zero degrees angle of attack is greater than that of a sphere at the same Reynolds number.

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FOREWORD

This research was supported by the Advanced Research Projects Agency, and was monitored by the Air Force Cambridge Research Laboratories under Contract No. F19628-67-C-0145. The project is being carried out under the direction of Mr. Lewis Grass and Captain Edward Young as Contract Monitors for the Air Force Cambridge Research Laboratories. Mr. Jerome Vorachek is the Goodyear Aerospace Project Engineer. The contractor's report number is GER 13731.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

MBOLS

C_D	drag coefficient, $\frac{drag}{q\mathrm{V}^{2/3}}$
C_L	lift coefficient, $\frac{lift}{q\mathrm{V}^{2/3}}$
C_m	pitching moment coefficient about tether point, $\frac{moment}{q\mathrm{V}}$
C_p	pressure coefficient, $\frac{p_{port} - p_{static}}{q}$
$C_{p_{internal}}$	pressure coefficient measured inside balloon shell
$C_{p_{local}}$	pressure coefficient measured in area of sting opening
C_x	axial force coefficient, $\frac{axial\ force}{q\mathrm{V}^{2/3}}$
M	free-stream Mach number
p_{port}	static pressure at a particular orifice (lb/ft^2)
p_{static}	free-stream static pressure (lb/ft^2)
q	dynamic pressure, $1/2\ \rho U^2$ (lb/ft^2)
R	Reynolds number based on max model diameter of 1.5 ft
U	free-stream velocity (ft/sec)
V	model volume (ft^3)
$\mathrm{V}^{2/3}$	reference area (ft^2)
α	model angle of attack (degrees)
ρ	free-stream density (slugs/ft^3)
'	superscript denoting coefficients uncorrected for sting opening

SECTION I

INTRODUCTION

One of the tethered balloon systems being considered for operation at extremely high altitudes (50,000 to 100,000 feet) is a natural shape balloon. As part of the research on the High-Altitude Tethered Balloon Systems Study under contract F19628-67-C-0145, wind tunnel tests of a rigid model of a natural shape balloon were conducted at Ames Aeronautical Laboratory of NASA.

The rigid model tested represented a shape with top loading $F/p = 0$, superpressure parameter $\alpha = 0.9315$, and $\Sigma = 0.0315$.

The wind tunnel investigation was performed to determine the effects of Reynolds number and angle of attack on the lift, pitching moment, drag, and surface pressure distribution on a natural shape balloon. The aerodynamic data were obtained for a Reynolds number range of 450,000 to 12 million. The data, reduced by NASA, were plotted and tabulated in coefficient form.

SECTION II

TEST SETUP AND PROCEDURE

1. WIND TUNNEL AND EQUIPMENT

The experimental data were obtained in the Ames Aeronautical Laboratory 12-foot pressure tunnel, which is a closed-circuit, variable-density wind tunnel that operates at subsonic speeds. The internal stagnation pressure can be varied fro 2.5 to 75 pounds per square inch absolute. A maximum Reynolds number of 9.5 million per foot can be obtained. A more detailed description of the facility is given in Reference 1.

The model was mounted on a sting, and the forces and moments were measured with an internal six-component balance. A dangleometer mounted internally was used to measure the model angle of attack. Recording of the pressure data was facilitated through the use of a 48-port scanning valve. Figure 1 is a rear view of the model mounted on the sting.

2. MODEL DESCRIPTION

The wind tunnel test model (Figure 2) consisted of a 1/8-inch thick shell with an internal platform and balance housing for sting attachment and equipment mounting. The natural shape balloon model represents a shape with top loading $F/p = 0$, superpressure parameter $\alpha = 0.9315$, and $\Sigma = 0.0315$. Use of the parameters to define the shape is explained in Reference 2. The shell was spun from 6061-T6 aluminum in two sections to permit access to the interior. During the test, the two halves were bolted together as shown in Figure 3. The screw heads were filled in with model wax to maintain a smooth surface. Pertinent details and dimensions of the model surface are presented in Table I. Measured coordinates were found to be within ±0.03 inch of the computer, or theoretical, coordinates.

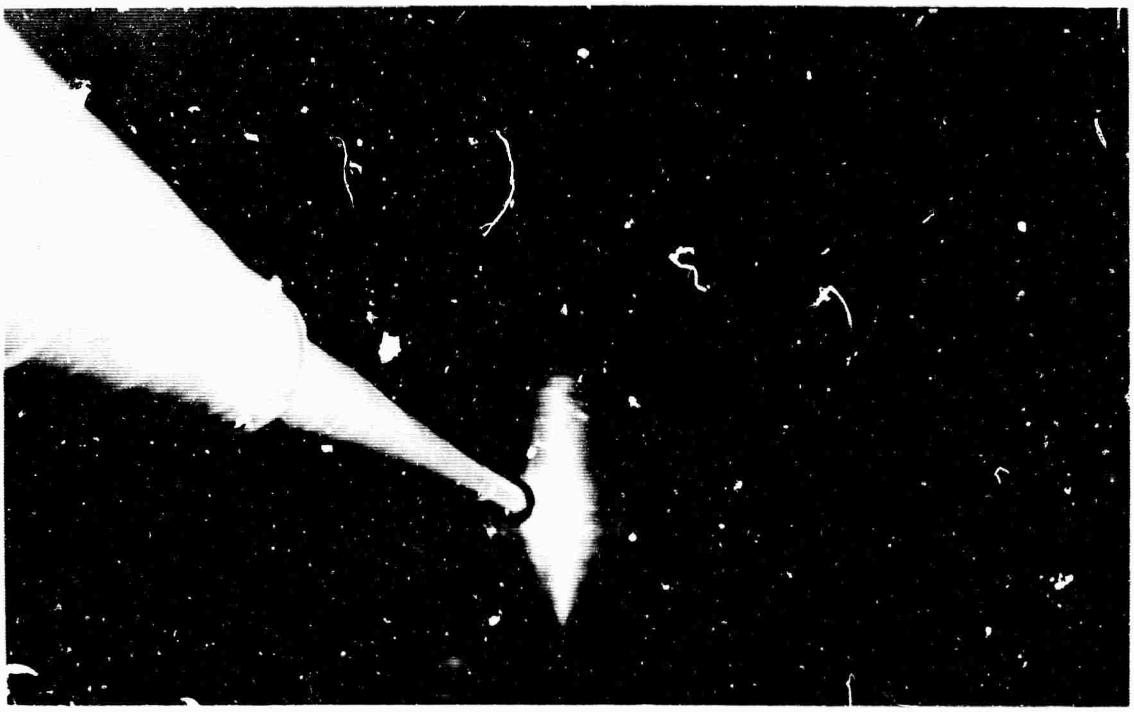


Figure 1. Rear View of Wind Tunnel Test Model

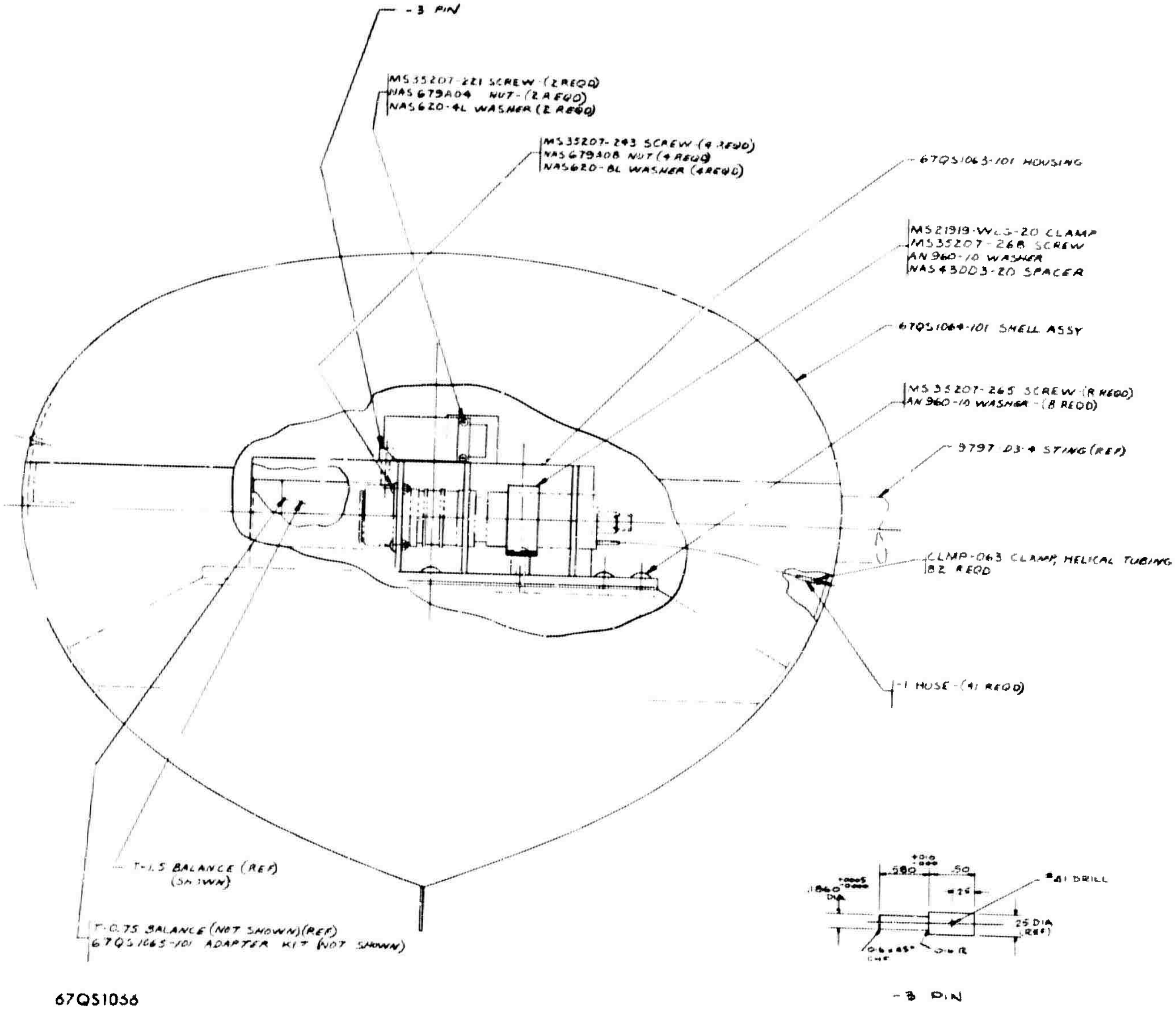


Figure 2. General Arrangement of Wind Tunnel Test Model

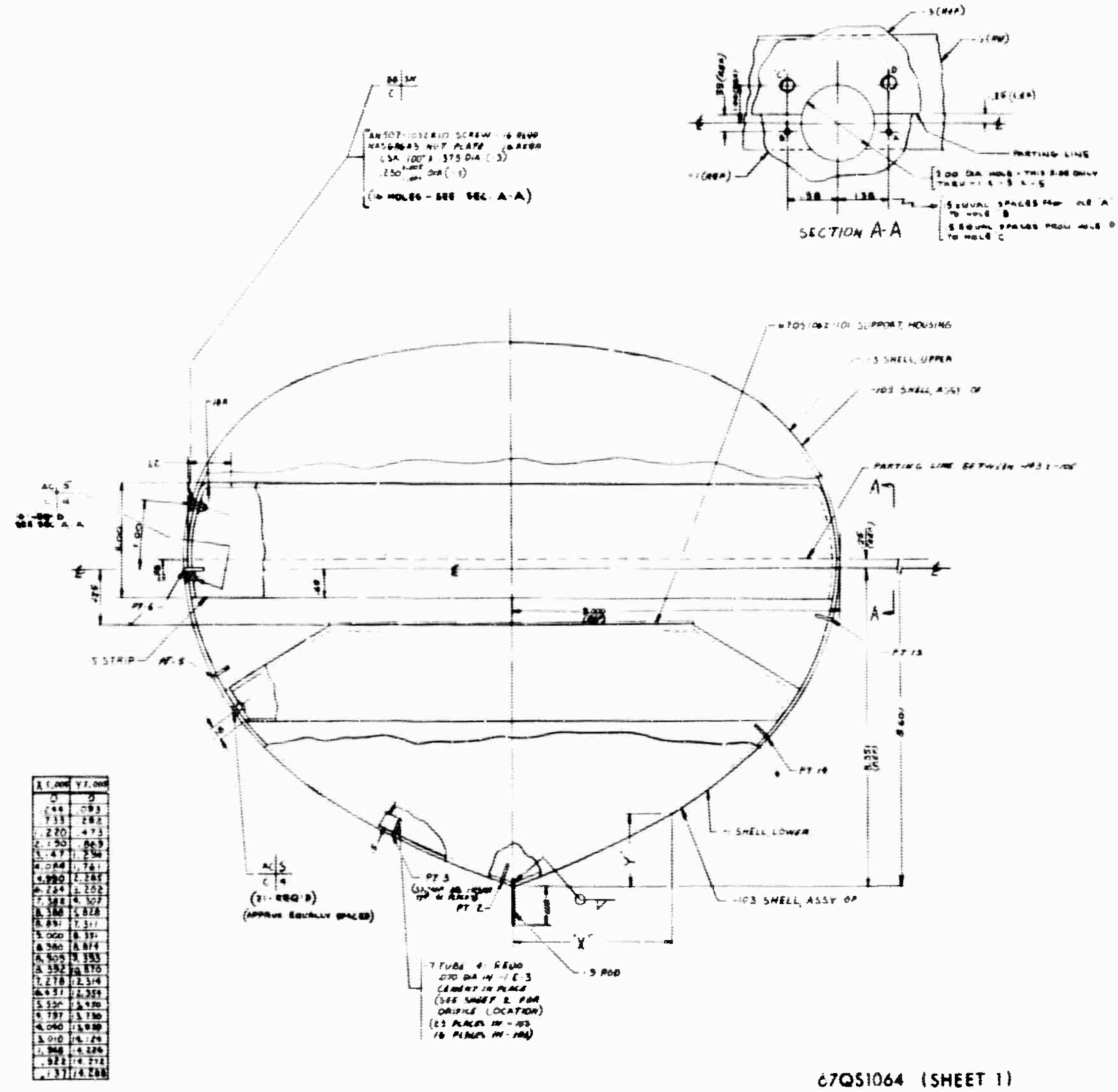
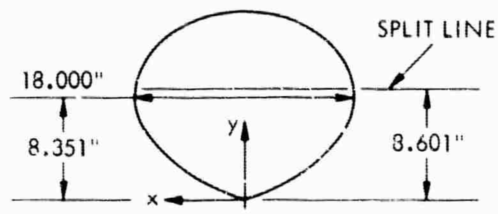


Figure 3. Shell Assembly

Table I. Model Coordinates



x (in.)	y (in.)	x (in.)	y (in.)	x (in.)	y (in.)	x (in.)	y (in.)
0.000	0.000	5.642	2.722	8.991	8.090	6.000	13.220
0.244	0.093	5.853	2.877	9.000	8.351	5.768	13.339
0.489	0.188	6.061	3.037	8.996	8.613	5.530	13.450
0.733	0.282	6.264	3.202	8.980	8.874	5.289	13.551
0.977	0.377	6.463	3.372	8.951	9.134	5.045	13.645
1.220	0.473	6.658	3.547	8.909	9.393	4.797	13.730
1.464	0.570	6.847	3.728	8.854	9.649	4.547	13.807
1.706	0.668	7.031	3.914	8.786	9.902	4.295	13.877
1.948	0.768	7.210	4.105	8.706	10.151	4.040	13.939
2.190	0.869	7.382	4.304	8.614	10.396	3.785	13.995
2.431	0.972	7.708	4.712	8.509	10.636	3.527	14.044
2.670	1.077	7.860	4.925	8.392	10.870	3.269	14.087
2.909	1.184	8.004	5.143	8.264	11.098	3.010	14.124
3.147	1.294	8.141	5.367	8.125	11.320	2.750	14.157
3.383	1.406	8.269	5.595	7.975	11.535	2.490	14.184
3.618	1.521	8.388	5.828	7.815	11.742	2.229	14.207
3.852	1.6[illegible]0	8.497	6.066	7.645	11.941	1.968	14.226
4.084	1.761	8.597	6.308	7.466	12.132	1.707	14.241
4.313	1.887	8.687	6.554	7.278	12.314	1.445	14.254
4.541	2.016	8.766	6.803	7.082	12.488	1.194	14.2[illegible]4
4.767	2.148	8.834	7.056	6.879	12.652	0.922	14.272
4.990	2.285	8.891	7.311	6.668	12.808	0.660	14.278
5.210	2.426	8.937	7.569	6.451	12.954	0.399	14.283
5.428	2.572	8.970	7.829	6.229	13.092	0.137	14.288

Forty-three pressure taps were positioned on the model surface as shown in Figure 4 to obtain the surface pressure distribution. Note in Figure 4 that the taps are located on only one side of the model. Since the flow is symmetrical in the horizontal plane, the pressure distribution on both sides of the model is the same. Hence, the pressures on one side only need be measured.

The pressure taps and 2-inch diameter hole for sting mounting are clearly shown in Figure 5, photograph of the assembled model. Figure 6 is a photograph of the interior of the model. The balance housing and adapter kit for the small balance have been removed from the interior platform and placed in front of the model. Note that the plastic tubing used for pressure measurements is shown.

3. TESTS AND PROCEDURE

Lift, drag, pitching moment, and pressure data, based on the maximum model diameter (1.5 feet), were obtained at Reynolds numbers of 0.45, 0.53, 0.78, 1.05, 5.00, and 12.00 million at a constant Mach number of 0.29. A six-degree, nose-up, bent sting was used so that the angle-of-attack scan was from -4 to +24 degrees. Inverting the model thus permitted an angle-of-attack range from -24 to +24 degrees.

A 1.5-inch diameter balance with a capacity of 300 pounds drag force was used in the Reynolds number range from one million to 12 million, and a 0.75-inch diameter balance with a capacity of 50 pounds drag force was used in the Reynolds number range below one million. This arrangement permitted the best possible resolution and accuracy of force measurements over the entire Reynolds number range.

4. REDUCTION OF DATA

The force and moment data were reduced by NASA to standard coefficient form as follows:

$$C_D' = \frac{\text{drag}}{q\mathcal{V}^{2/3}} \tag{1}$$

$$C_L' = \frac{\text{lift}}{q\mathcal{V}^{2/3}} \tag{2}$$

$$C_m = \frac{\text{pitching moment}}{q\mathcal{V}} \tag{3}$$

where

q is the free-stream dynamic pressure (lb/ft^2)

$\mathcal{V}$ is the model volume ($1.275\ ft^3$)

$\mathcal{V}^{2/3}$ is the reference area ($1.176\ ft^2$)

POINTS	DISTANCE BETWEEN POINTS
10-9	3.0
9-8	3.0
8-7	3.0
6-5	3.2
5-4	3.2
4-3	3.2
10-11	4.4
11-12	4.4
13-14	4.0
10-21	6.0
21-20	3.0
19-18	3.2
18-17	3.2
17-16	3.2
10-46	4.4
46-45	4.4
42-43	4.0
10-30	6.0
30-29	3.0
28-27	3.2
27-26	3.2
26-25	3.2
10-41	4.4
41-40	4.4
37-38	4.0
10-36	4.4
36-35	4.4
32-33	4.0

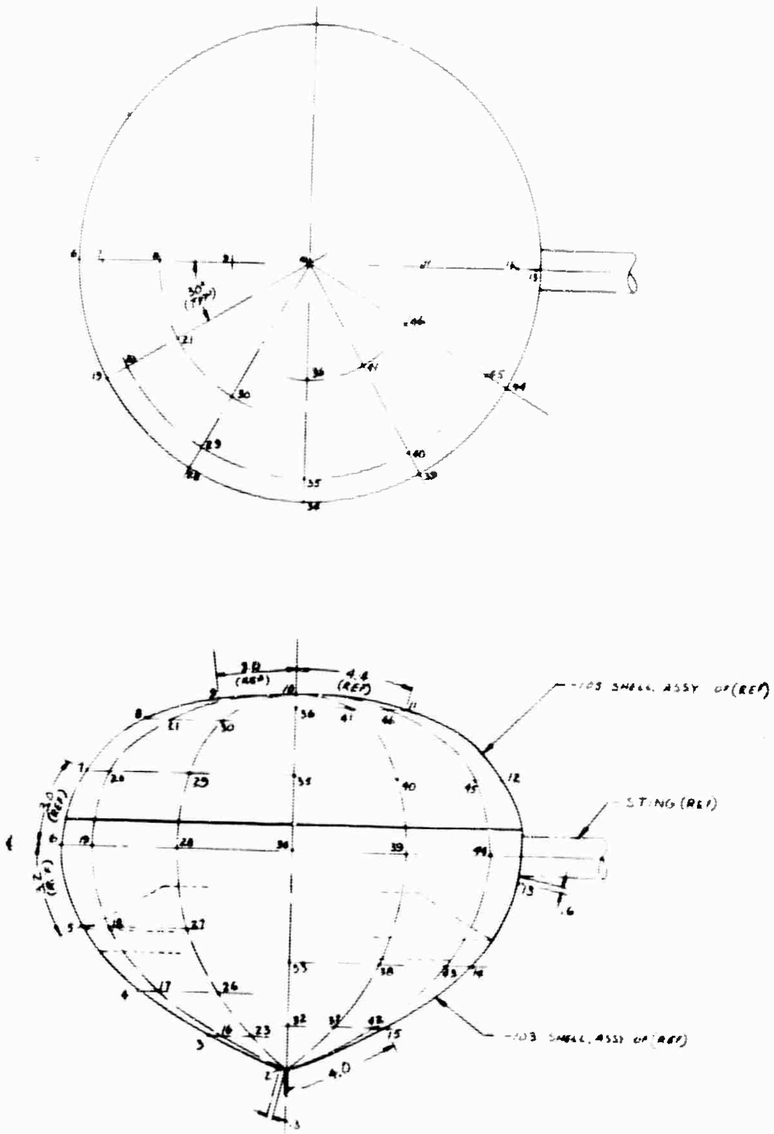


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Figure 4. Location of External Pressure Orifices

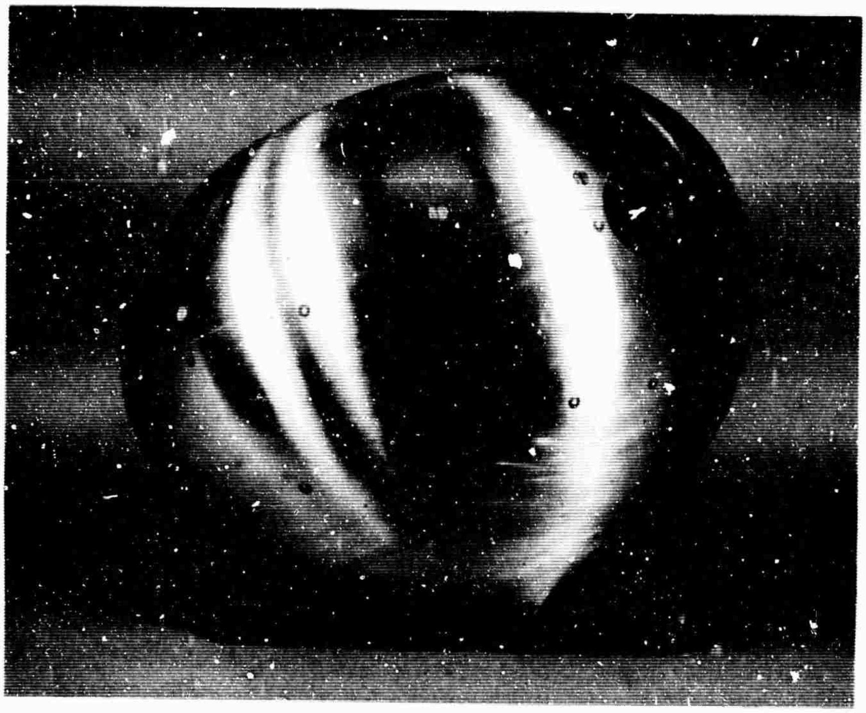

Figure 5. Photograph of Assembled Model

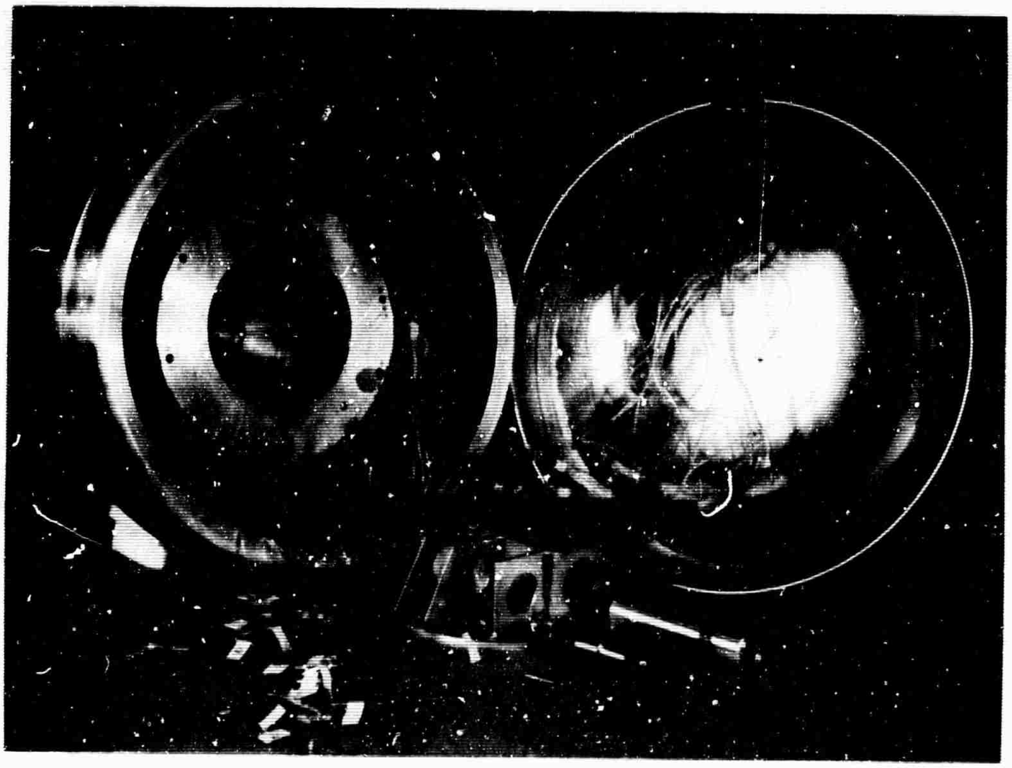

Figure 6. Photograph of Disassembled Model

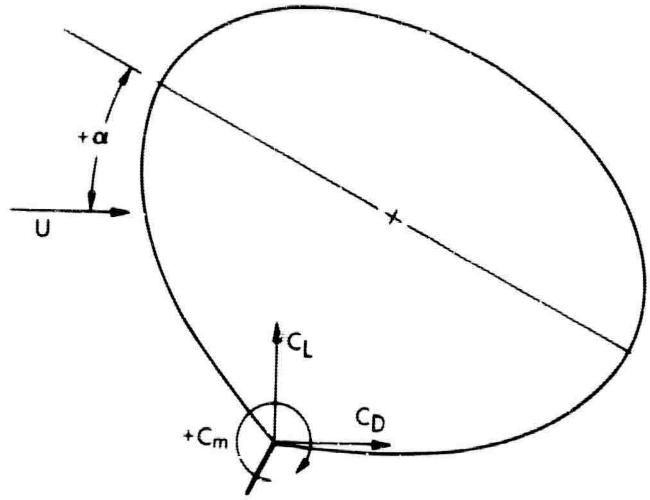

Figure 7. Aerodynamic Sign Convention for Balloon

The reference axes are wind (stability) axes, and the moment center is the balloon tether point. Figure 7 illustrates the sign convention employed and shows the location of the model moment center.

Since a portion of the model surface was removed to allow attachment to the sting, it was necessary to apply a base pressure and internal pressure correction to the lift and drag. The axial force coefficient can be written as

$$C_X = C_X' + C_{p_{internal}} \left(\frac{\pi d^2_{hole}}{4V^{2/3}}\right) - C_{p_{local}} \left(\frac{\pi d^2_{hole}}{4V^{2/3}}\right)$$

$$= C_X' + \left(C_{p_{internal}} - C_{p_{local}}\right) \left(\frac{\pi d^2_{hole}}{4}\right) \left(\frac{1}{V^{2/3}}\right) \tag{4}$$

With this pressure correction, Equations 1 and 2 can be written as

$$C_D = C_D' + \left(C_{p_{internal}} - C_{p_{local}}\right) \left(\frac{\pi d^2_{hole}}{4}\right) \left(\frac{1}{V^{2/3}}\right) \cos \alpha_{model} \tag{5}$$

$$C_L = C_L' - \left(C_{p_{internal}} - C_{p_{local}}\right) \left(\frac{\pi d^2_{hole}}{4}\right) \left(\frac{1}{V^{2/3}}\right) \sin \alpha_{model} \tag{6}$$

The pressure coefficients were reduced to standard coefficient form as follows:

$$C_p = \frac{p_{port} - p_{static}}{q} \tag{7}$$

SECTION III

TEST RESULTS

1. GENERAL

Lift, pitching moment, and drag data were plotted in coefficient form against angle of attack. The force and surface pressure data were tabulated in coefficient form. The tabulated force data are given in Tables II through XII. The surface pressure data are given in the Appendix. The lift, pitching moment, and drag data plots are discussed in the following paragraphs.

2. LIFT DATA

In general, at all Reynolds numbers, the lift curves (Figures 8 through 12) exhibit a common trend with angle of attack. Zero lift occurs at some negative angle of attack, while positive lift exists at zero angle of attack for Reynolds numbers to 1 million. For a Reynolds number of 12 million (Figure 12), the model exhibits negative lift at zero angle of attack; however, the slope through zero angle of attack is still positive. The model generally stalled at some angle of attack. An exception to each of these trends occurs at a Reynolds number of 5 million (Figure 11). In this case, the data points are quite scattered, not showing any continuous pattern. Comparison of visual observations for each run indicated larger amplitude vibrations of the model during this particular run. This could be the manifestation of unsteady flow and would explain the scattering of the data.

3. PITCHING MOMENT DATA

Aerodynamic pitching moment data about the model tether point are plotted in Figures 13 through 17. At each Reynolds number, the model exhibits a negative pitching moment at zero angle of attack. Zero pitching moment occurs at some positive angle of attack, generally between 5 and 15 degrees; however, this trim condition is an unstable one since the slope of the moment curve is positive. In practice, the restoring moment due to buoyancy will overcome the unstable aerodynamic moment, resulting in a stable configuration.

Again, there is some scatter of data at a Reynolds number of 5 million (Figure 16), though not so severe as the lift data at the same condition. The slope of the moment curve at negative angles of attack for the 5 million Reynolds number condition is definitely negative, whereas the moment curves for the other Reynolds numbers flatten out or become slightly positive in slope at negative angles of attack.

4. DRAG DATA

The drag data are plotted in coefficient form against angle of attack in Figures 18 through 22. The model generally exhibits increasing drag below zero degrees angle of attack. Between 0 and 10 degrees angle of attack, the drag decreases suddenly, then slowly increases with increasing angle of attack.

Figure 23 is a plot of drag coefficient at zero degrees angle of attack as a function of Reynolds number. Also plotted in Figure 23 is an average drag curve for a sphere in still air (zero turbulence), which was taken from Reference 3. Data on the tunnel turbulence level was unavailable, but if the turbulence is considered negligible, then a direct comparison between balloon drag and sphere drag can be made. Examination of the experimental data reveals that the drag of the natural shape balloon is somewhat higher than that of the sphere. In particular, the drag of the balloon model increases in the supercritical region (Reynolds number greater than 1 million), whereas the sphere drag curve flattens out. At the higher Reynolds numbers, however, the sphere drag curve is an extrapolation recommended by Hoerner (Reference 4) and is not based on experimental data.

The transition region for the balloon can not be fixed at this time, since no runs at Reynolds numbers below 440,000 were made; however, it does appear from the available data that the transition region for the balloon is wider than that of the sphere.

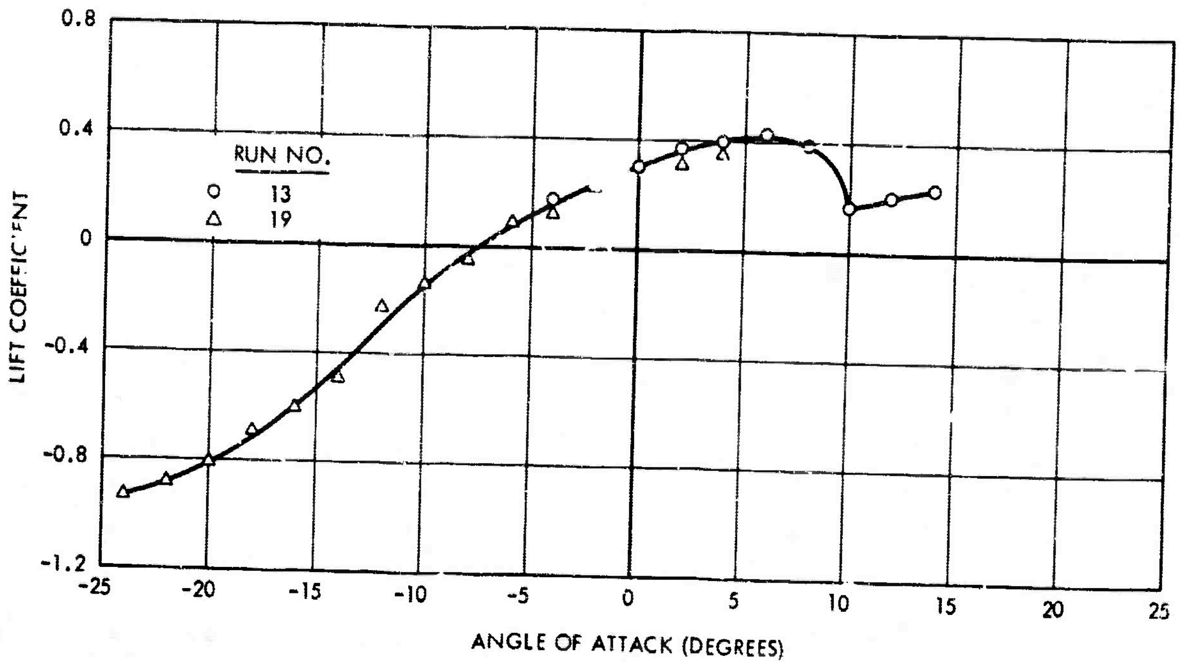

Figure 8. Balloon Lift Coefficient Versus Angle of Attack Reynolds Number = 0.45 Million

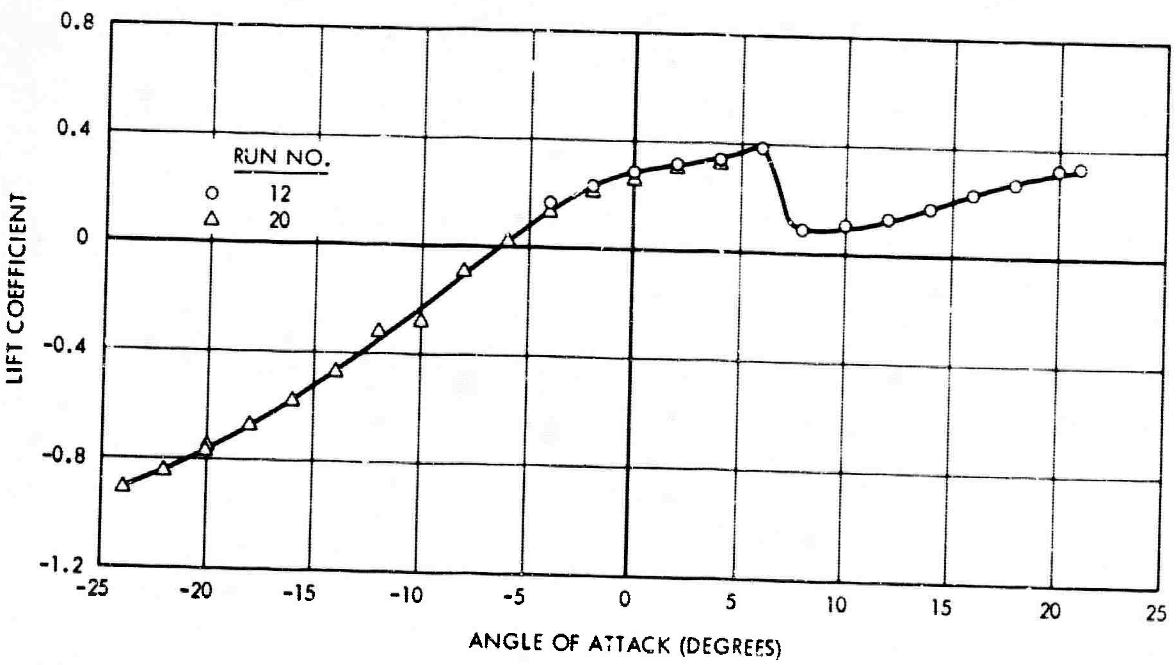

Figure 9. Balloon Lift Coefficient Versus Angle of Attack Reynolds Number = 0.53 Million

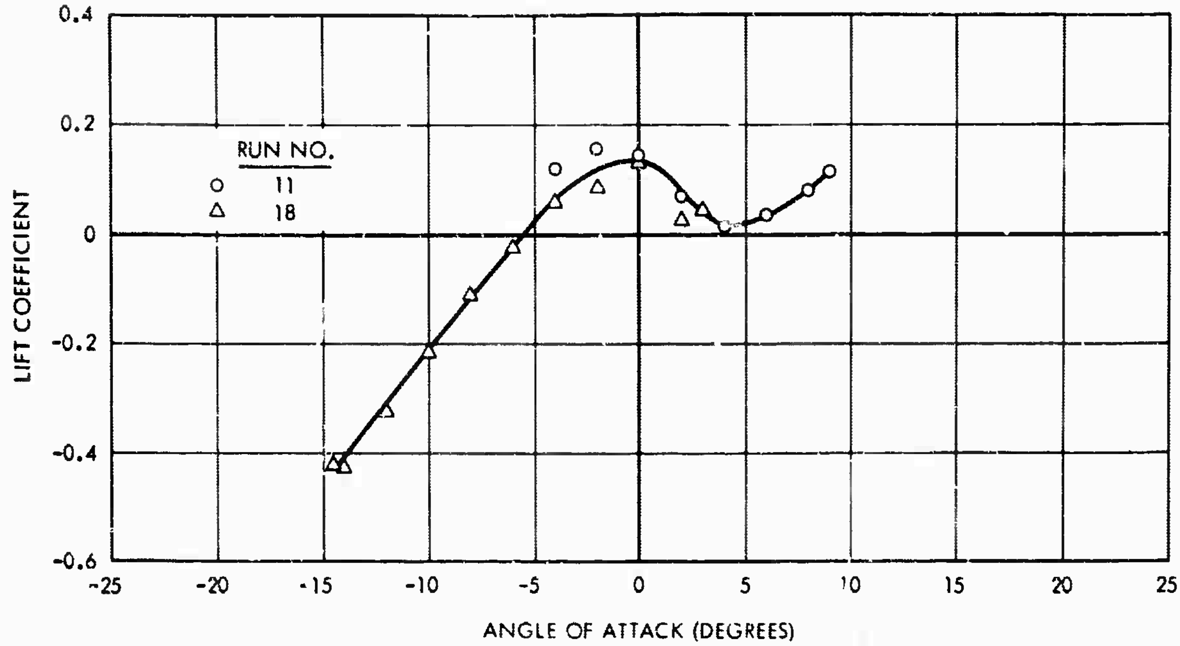

Figure 10. Balloon Lift Coefficient Versus Angle of Attack
Reynolds Number = 1.05 Million

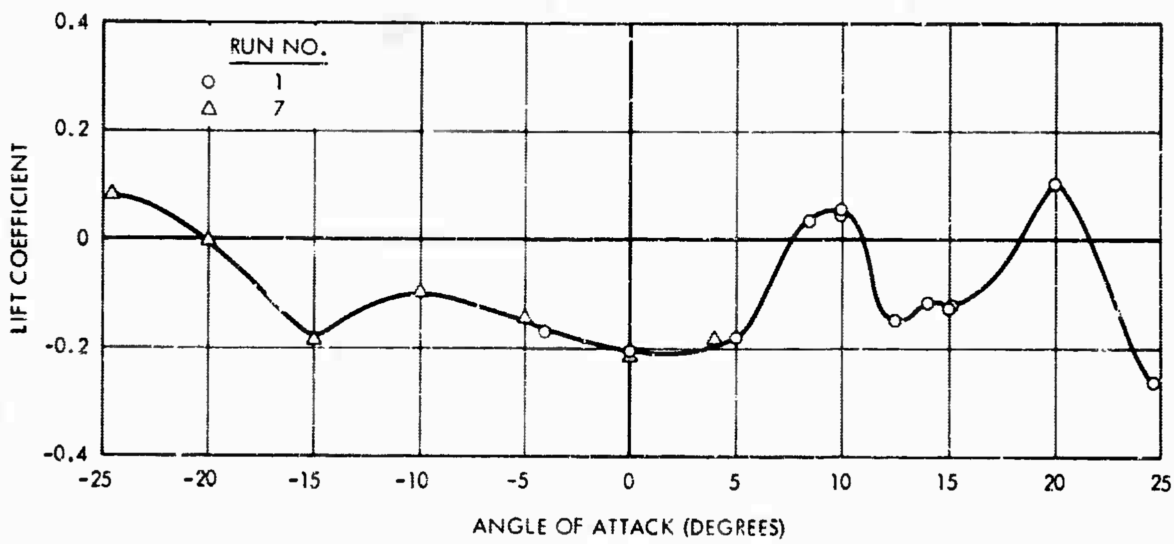

Figure 11. Balloon Lift Coefficient Versus Angle of Attack
Reynolds Number = 5 Million

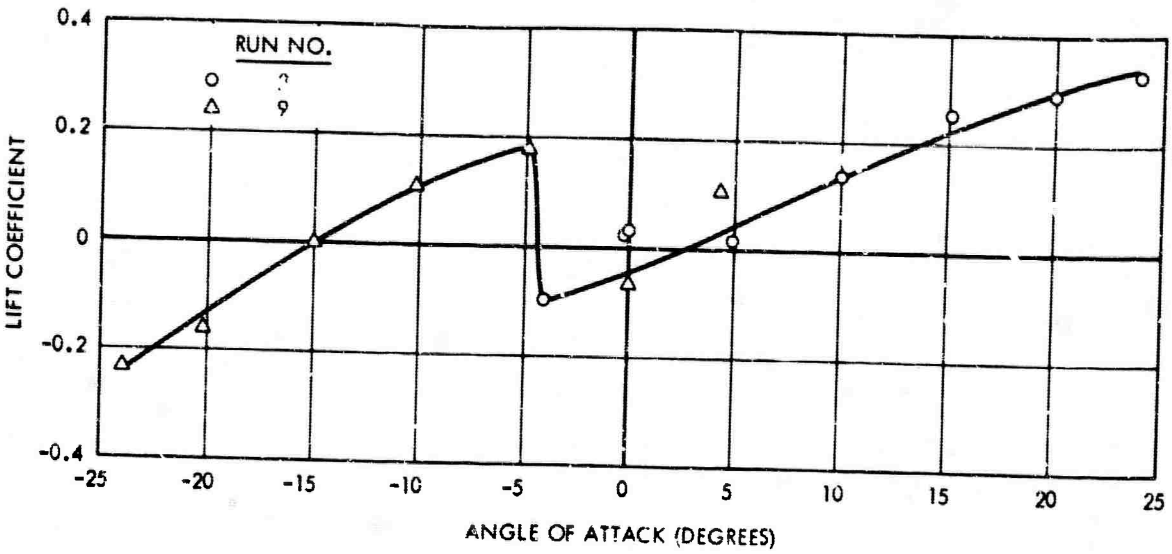

Figure 12. Balloon Lift Coefficient Versus Angle of Attack Reynolds Number = 12 Million

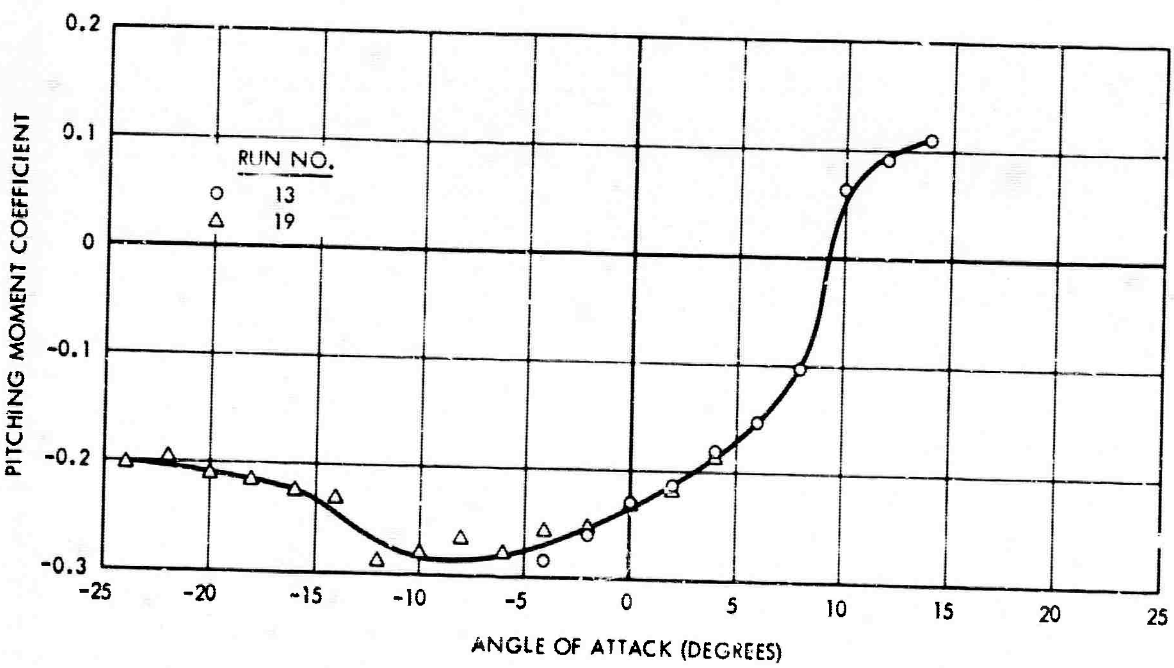

Figure 13. Balloon Pitching Moment Coefficient Versus Angle of Attack Reynolds Number = 0.45 Million

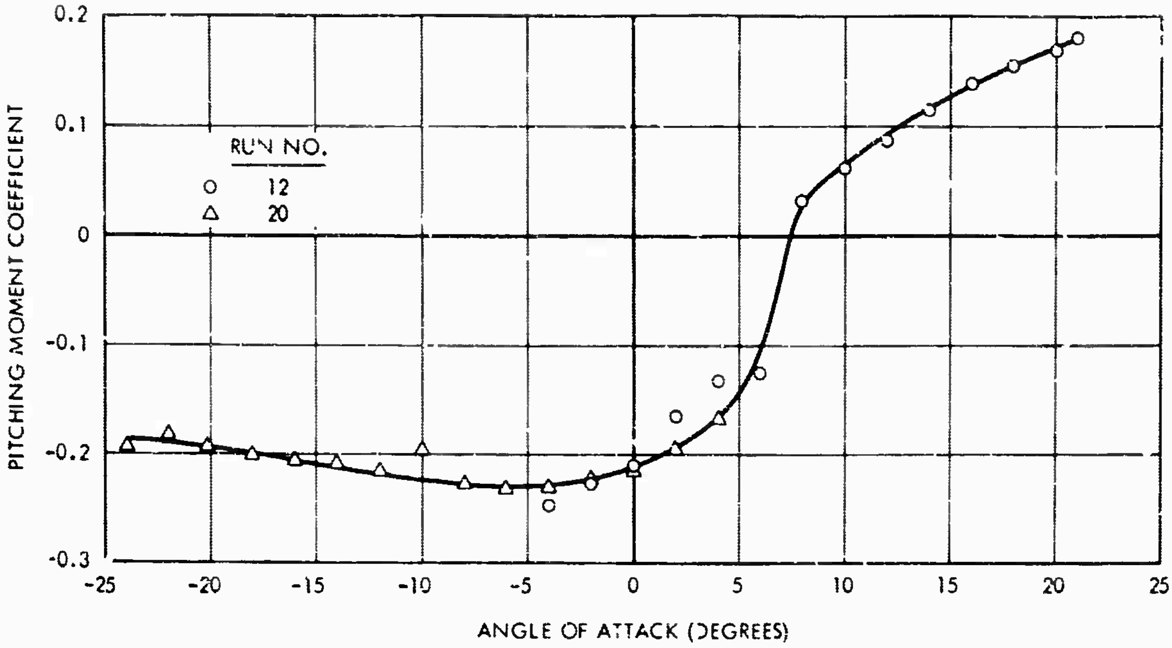

Figure 14. Balloon Pitching Moment Coefficient Versus Angle of Attack Reynolds Number = 0.53 Million

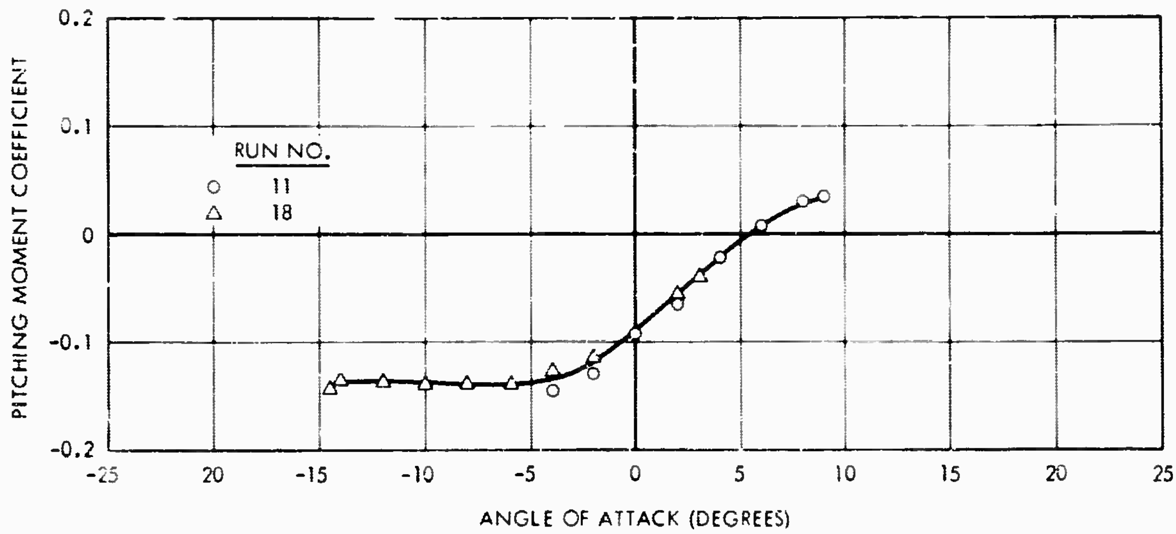

Figure 15. Balloon Pitching Moment Coefficient Versus Angle of Attack Reynolds Number = 1.05 Million

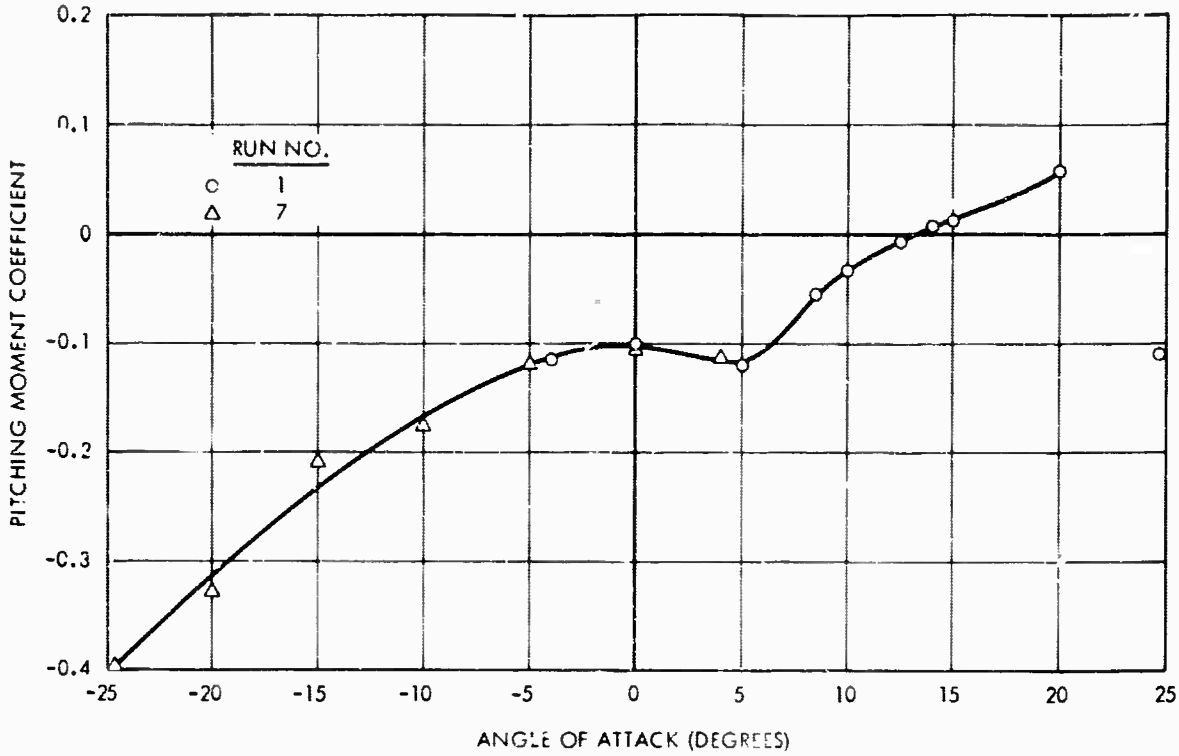

Figure 16. Balloon Pitching Moment Coefficient Versus Angle of Attack Reynolds Number = 5 Million

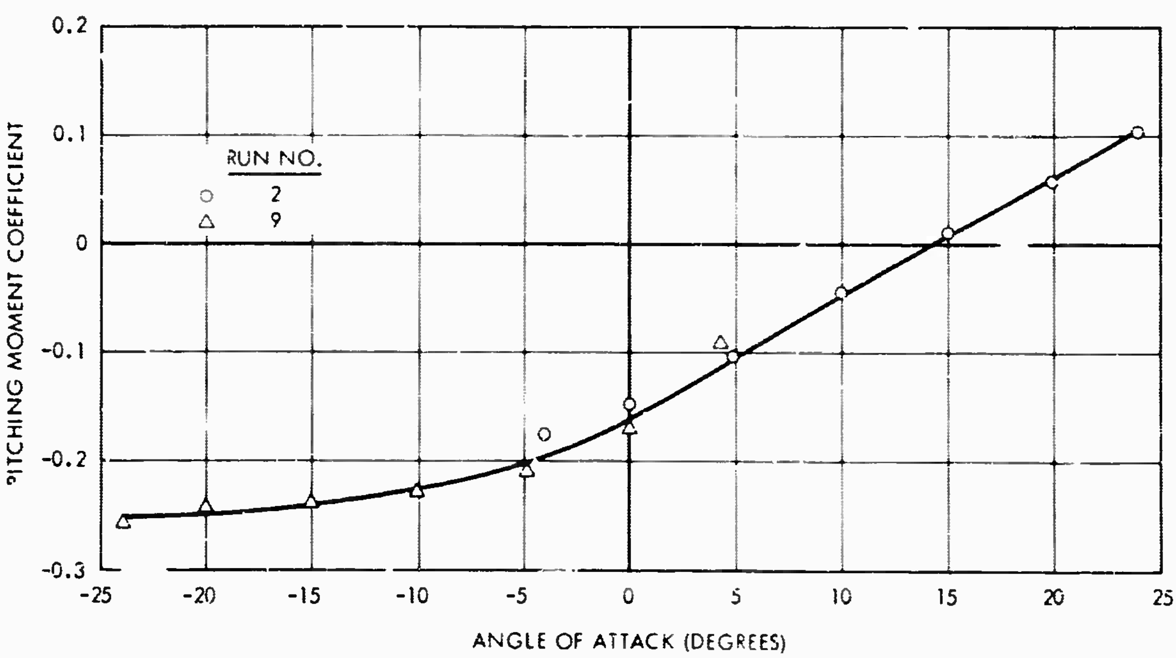

Figure 17. Balloon Pitching Moment Coefficient Versus Angle of Attack Reynolds Number = 12 Million

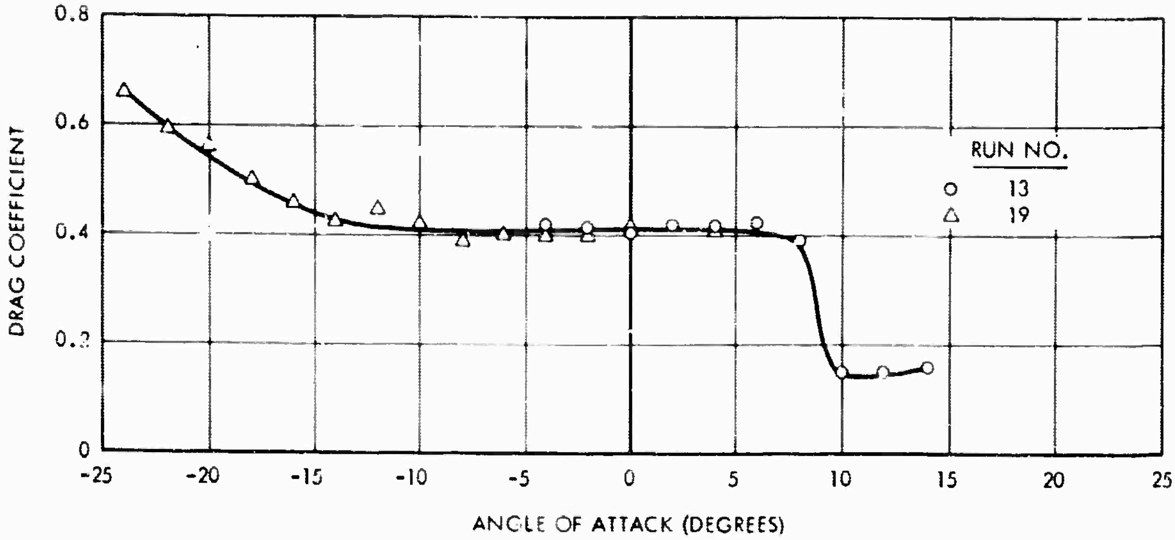

Figure 18. Balloon Drag Coefficient Versus Angle of Attack Reynolds Number = 0.45 Million

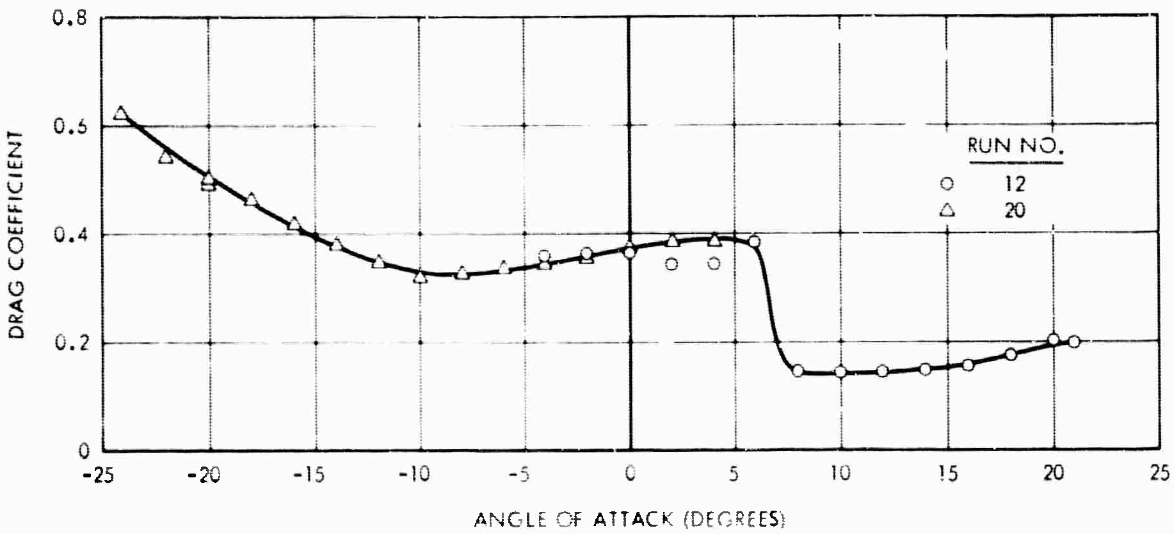

Figure 19. Balloon Drag Coefficient Versus Angle of Attack Reynolds Number = 0.53 Million

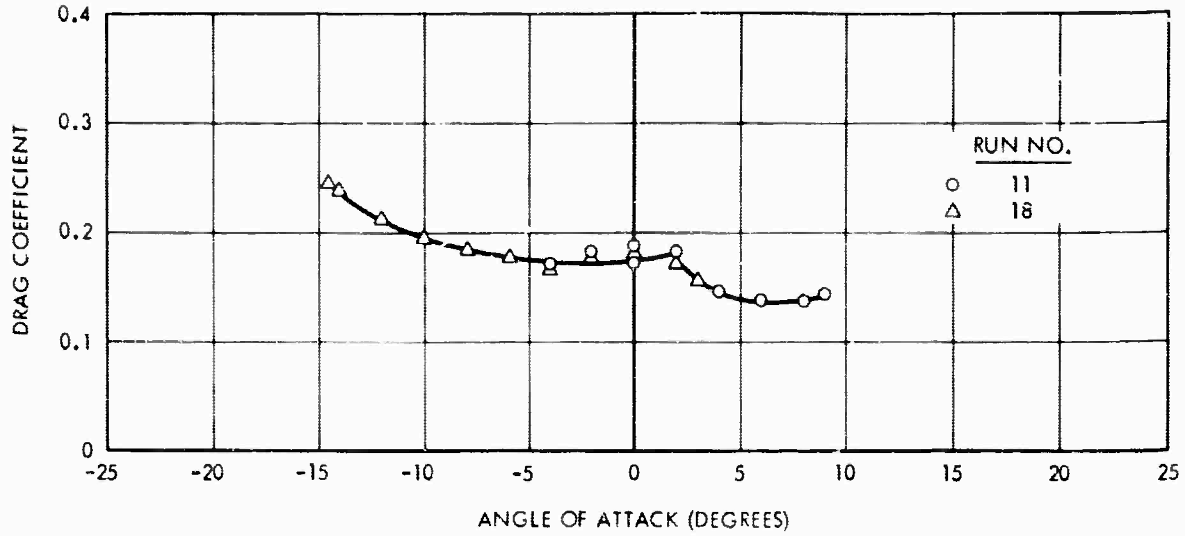

Figure 20. Balloon Drag Coefficient Versus Angle of Attack
Reynolds Number = 1.05 Million

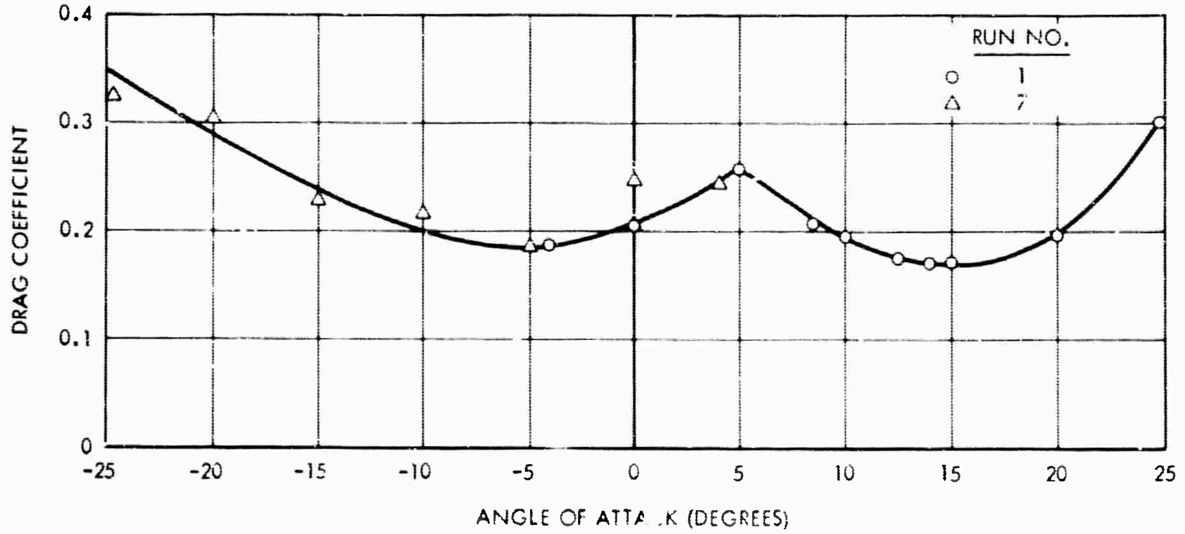

Figure 21. Balloon Drag Coefficient Versus Angle of Attack
Reynolds Number = 5 Million

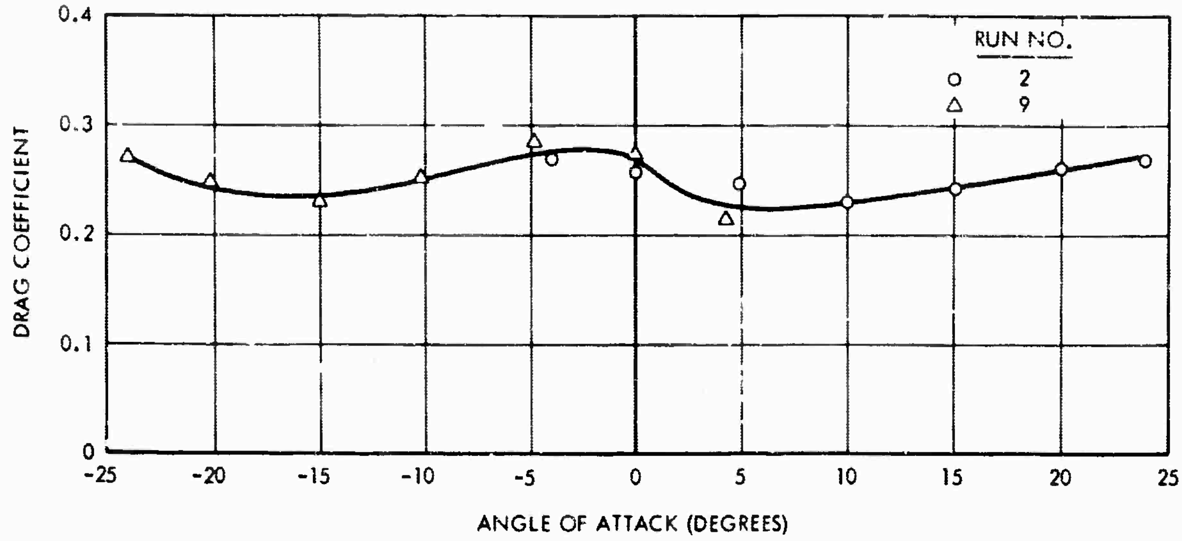

Figure 22. Balloon Drag Coefficient Versus Angle of Attack Reynolds Number = 12 Million

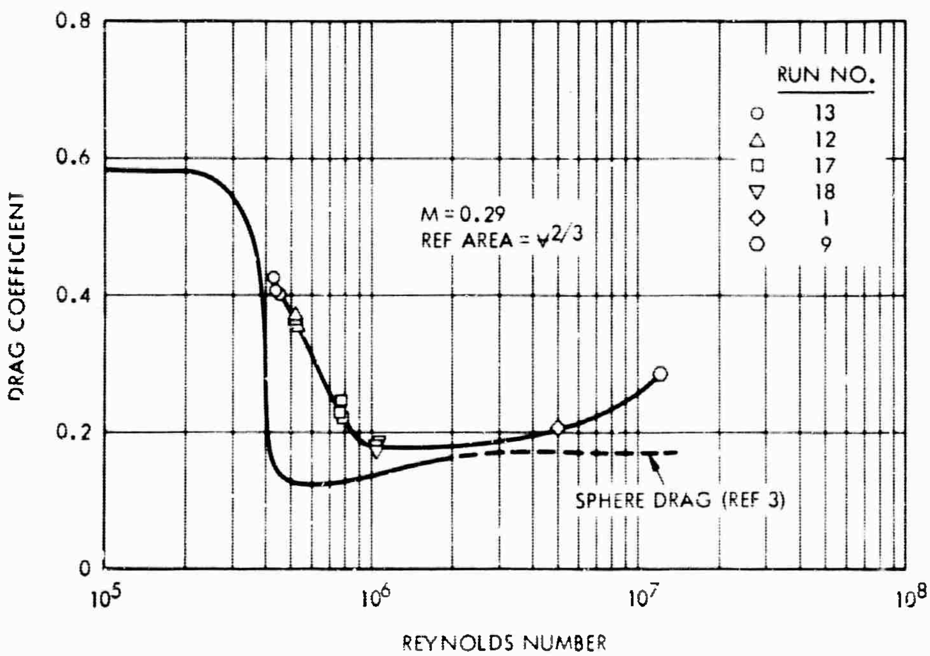

Figure 23. Balloon Drag Coefficient at Zero Angle of Attack Versus Reynolds Number

Table II. Force Data - Run No. 1, Dynamic Pressure = 212.9 Lb/Ft^2

M	α (degrees)	R (millions)	C_L	C_D	C_m
0.290	-3.95	5.06	-0.170	0.189	0.115
0.289	0.04	5.05	-0.207	0.205	-0.103
0.290	5.02	5.05	-0.180	0.257	-0.119
0.290	10.05	5.05	0.047	0.194	-0.031
0.289	15.08	5.03	-0.128	0.168	0.013
0.288	8.52	5.01	0.036	0.209	-0.055
0.289	10.03	5.02	0.058	0.194	-0.027
0.289	12.54	5.02	-0.148	0.175	-0.006
0.289	13.96	5.02	-0.117	0.173	0.008
0.289	15.15	5.02	-0.121	0.172	0.014
0.290	20.06	5.02	0.104	0.196	0.058
0.288	24.75	5.00	-0.260	0.302	-0.110
0.290	0.04	5.02	-0.202	0.203	-0.100

Table III. Force Data - Run No. 2, Dynamic Pressure = 526.2 Lb/Ft^2

M	α (degrees)	R (millions)	C_L	C_D	C_m
0.283	0.14	12.03	0.030	0.256	-0.142
0.283	-4.06	12.01	-0.095	0.270	-0.176
0.283	-0.08	12.00	0.033	0.259	-0.147
0.282	4.90	11.97	0.017	0.248	-0.103
0.282	10.06	11.97	0.138	0.230	-0.044
0.282	15.11	11.96	0.252	0.243	0.012
0.281	19.95	11.91	0.290	0.261	0.058
0.281	23.92	11.91	0.327	0.269	0.104
0.281	-0.22	11.90	0.025	0.269	-0.151

Table IV. Force Data - Run No. 7, Dynamic Pressure = 215.7 Lb/Ft^2

M	α (degrees)	R (millions)	C_L	C_D	C_m
0.291	0.02	5.04	-0.209	0.246	-0.136
0.290	4.02	5.03	-0.182	0.242	-0.112
0.290	-0.01	5.03	-0.198	0.242	-0.133
0.290	-4.99	5.03	-0.142	0.185	-0.120
0.291	-10.01	5.01	-0.099	0.217	-0.176
0.290	-15.06	5.00	-0.184	0.230	-0.209
0.290	-19.99	5.00	-0.005	0.366	-0.329
0.290	-24.63	5.00	0.082	0.326	-0.397
0.290	0.0	4.99	-0.179	0.203	-0.104

Table V. Force Data - Run No. 9, Dynamic Pressure = 524.2 Lb/Ft^2

M	α (degrees)	R (millions)	C_L	C_D	C_m
0.283	0.03	12.14	-0.095	0.284	-0.173
0.283	4.29	12.11	0.105	0.214	-0.091
0.282	0.04	12.06	-0.048	0.284	-0.173
0.282	-4.85	12.05	0.178	0.285	-0.210
0.282	-10.18	12.05	0.106	0.252	-0.229
0.282	-15.00	12.04	-0.001	0.231	-0.238
0.282	-20.20	12.04	-0.162	0.248	-0.243
0.282	-23.89	12.02	-0.231	0.272	-0.257
0.282	-0.04	12.01	-0.069	0.285	-0.174

Table VI. Force Data - Run No. 11, Dynamic Pressure = 44.7 Lb/Ft^2

M	α (degrees)	R (millions)	C_L	C_D	C_m
0.296	0.01	1.05	0.163	0.188	-0.102
0.297	-3.98	1.06	0.120	0.172	-0.146
0.297	-2.00	1.06	0.157	0.183	-0.130
0.296	0.0	1.05	0.145	0.172	-0.090
0.296	2.03	1.05	0.070	0.183	-0.065
0.295	4.02	1.05	0.015	0.146	-0.022
0.296	6.03	1.06	0.036	0.138	0.007
0.296	8.05	1.06	0.080	0.138	0.030
0.295	9.04	1.06	0.112	0.144	0.034
0.294	0.02	1.05	0.120	0.180	-0.092

Table VII. Force Data - Run No. 12, Dynamic Pressure = 21.6 Lb/Ft^2

M	α (degrees)	R (millions)	C_L	C_D	C_m
0.293	0.03	0.52	0.287	0.367	-0.208
0.294	-4.00	0.52	0.164	0.359	-0.247
0.295	-1.98	0.52	0.233	0.361	-0.227
0.294	0.03	0.52	0.290	0.371	-0.211
0.294	2.03	0.52	0.319	0.342	-0.164
0.294	4.03	0.52	0.340	0.345	-0.133
0.294	6.03	0.53	0.388	0.384	-0.125
0.292	8.03	0.53	0.089	0.147	0.033
0.292	10.06	0.53	0.108	0.144	0.062
0.293	12.04	0.53	0.137	0.147	0.087
0.289	14.06	0.53	0.177	0.149	0.114
0.290	16.07	0.53	0.233	0.156	0.139
0.288	18.07	0.53	0.272	0.175	0.155
0.289	20.09	0.53	0.325	0.205	0.167
0.289	21.07	0.54	0.314	0.198	0.180
0.284	0.0	0.53	0.273	0.356	-0.201

Table VIII. Force Data - Run No. 13, Dynamic Pressure = 17.8 Lb/Ft^2

M	α (degrees)	R (millions)	C_L	C_D	C_m
0.291	0.01	0.43	0.325	0.427	-0.246
0.292	-3.99	0.43	0.182	0.420	-0.285
0.293	-2.00	0.43	0.245	0.415	-0.261
0.294	0.01	0.44	0.304	0.404	-0.230
0.293	2.03	0.44	0.368	0.420	-0.213
0.294	4.04	0.45	0.399	0.419	-0.181
0.294	6.03	0.45	0.434	0.427	-0.153
0.295	8.05	0.45	0.392	0.391	-0.102
0.295	10.04	0.45	0.168	0.151	0.063
0.295	12.06	0.45	0.201	0.149	0.092
0.295	14.07	0.46	0.235	0.158	0.115
0.293	0.02	0.46	0.290	0.402	-0.229

Table IX. Force Data - Run No. 17, Dynamic Pressure = 34.3 Lb/Ft^2

M	α (degrees)	R (millions)	C_L	C_D	C_m
0.305	0.01	0.77	0.193	0.229	-0.128
0.305	4.02	0.77	0.170	0.240	-0.071
0.305	2.00	0.78	0.163	0.239	-0.100
0.305	0.0	0.78	0.143	0.245	-0.128
0.304	-2.00	0.78	0.118	0.234	-0.146
0.304	-4.00	0.78	0.041	0.215	-0.146
0.301	-6.01	0.78	-0.051	0.226	-0.160
0.299	0.01	0.78	0.141	0.221	-0.119

Table X. Force Data - Run No. 18, Dynamic Pressure = 46.7 Lb/Ft^2

M	α (degrees)	R (millions)	C_L	C_D	C_m
0.304	-0.01	1.05	0.129	0.172	-0.093
0.304	3.07	1.05	0.044	0.156	-0.041
0.303	2.01	1.05	0.026	0.173	-0.055
0.302	0.01	1.05	0.098	0.176	-0.085
0.302	-1.99	1.06	0.085	0.177	-0.115
0.302	-4.00	1.06	0.059	0.168	-0.128
0.300	-6.01	1.06	-0.023	0.177	-0.139
0.300	-8.03	1.06	-0.110	0.184	-0.140
0.300	-10.01	1.07	-0.215	0.196	-0.139
0.300	-12.02	1.07	-0.322	0.213	-0.137
0.299	-14.04	1.07	-0.425	0.239	-0.136
0.298	-14.53	1.07	-0.420	0.245	-0.145
0.297	0.0	1.08	0.130	0.183	-0.100

Table XI. Force Data - Run No. 19, Dynamic Pressure = 18.5 Lb/Ft^2

M	α (degrees)	R (millions)	C_L	C_D	C_m
0.299	-0.01	0.44	0.293	0.412	-0.240
0.299	4.04	0.44	0.353	0.411	-0.187
0.297	1.99	0.44	0.313	0.421	-0.219
0.298	0.0	0.44	0.275	0.399	-0.231
0.299	-1.98	0.45	0.234	0.399	-0.252
0.299	-4.00	0.45	0.122	0.398	-0.258
0.298	-6.00	0.45	0.088	0.401	-0.279
0.299	-8.03	0.45	-0.052	0.390	-0.267
0.299	-10.01	0.45	-0.140	0.424	-0.280
0.294	-12.03	0.45	-0.226	0.448	-0.289
0.295	-14.03	0.45	-0.487	0.427	-0.231
0.294	-16.03	0.45	-0.596	0.459	-0.225
0.294	-18.05	0.45	-0.687	0.501	-0.217
0.294	-20.09	0.45	-0.803	0.561	-0.213
0.293	-22.05	0.45	-0.879	0.592	-0.197
0.292	-24.05	0.46	-0.937	0.659	-0.203
0.289	0.01	0.46	0.281	0.391	-0.227

Table XII. Force Data - Run No. 20, Dynamic Pressure = 22.4 Lb/Ft^2

M	α (degrees)	R (millions)	C_L	C_D	C_m
0.30[illegible]	0.02	0.52	0.267	0.374	-0.215
0.305	4.04	0.52	0.331	0.386	-0.167
0.304	2.01	0.52	0.303	0.382	-0.195
0.302	0.0	0.52	0.260	0.372	-0.213
0.301	-1.99	0.52	0.217	0.351	-0.223
0.302	-3.98	0.53	0.126	0.342	-0.230
0.300	-6.01	0.53	0.020	0.338	-0.232
0.300	-6.02	0.53	0.014	0.338	-0.227
0.301	-8.02	0.53	-0.090	0.323	-0.228
0.299	-10.00	0.53	-0.281	0.319	-0.197
0.299	-12.02	0.53	-0.325	0.348	-0.216
0.299	-14.03	0.53	-0.475	0.380	-0.209
0.298	-16.04	0.53	-0.581	0.418	-0.207
0.297	-18.04	0.53	-0.675	0.461	-0.202
0.297	-20.15	0.54	-0.773	0.501	-0.194
0.295	-20.06	0.54	-0.754	0.493	-0.196
0.295	-22.06	0.54	-0.853	0.541	-0.183
0.294	-24.08	0.54	-0.914	0.621	-0.195
0.294	0.0	0.54	0.226	0.330	-0.189

SECTION IV

CONCLUSIONS

Results of the wind tunnel investigation to determine the effects of Reynolds number and angle of attack on the lift, pitching moment, drag, and surface pressure distribution of the natural shape balloon indicate the following:

(1) Positive lift exists at zero degrees angle of attack for Reynolds numbers to 1 million; negative lift exists at higher Reynolds numbers.

(2) A form of stall occurs at a positive angle of attack generally less than 10 degrees.

(3) An aerodynamically unstable trim point occurs between 5 and 15 degrees angle of attack. In practice, the restoring moment due to buoyancy will overcome the unstable aerodynamic moment, resulting in a stable configuration.

(4) The drag at zero degrees angle of attack is greater than that of a sphere at the same Reynolds number.

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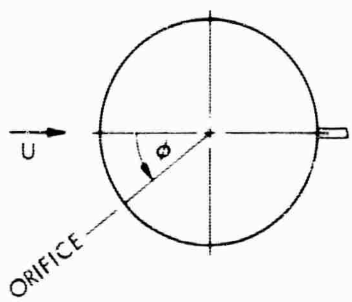
APPENDIX

SURFACE PRESSURE DISTRIBUTION DATA

The surface pressure data for conditions of α, R, q, and M are tabulated in coefficient form in this appendix. Forty-three pressure taps were positioned on the model surface to obtain the surface pressure distribution. Values given for pressure tap No. 47 are internal pressure coefficients. The polar coordinates of the surface pressure taps are shown in Table XIII. These taps are listed in the first column in Tables XIV through XIX, which give the pressure coefficient for each tap at varying Reynolds numbers and angles of attack.

Table XIII. Polar Coordinates of Pressure Taps

ϕ \ θ	-88°	-60.4°	-60°	-40°	-30.8°	-19.6°	-6.6°	0°	19.6°	40°	51.5°	57.3°	90°
0°	2	3		4		5		6	7	8		9	10
30°		16		17		18		19	20	21		22	10
60°		23		26		27		28	29	30		31	10
90°			32		33			34	35		36		10
120°			37		38			39	40		41		10
150°			42		43			44	45		46		10
180°			15		14		13		12		11		10



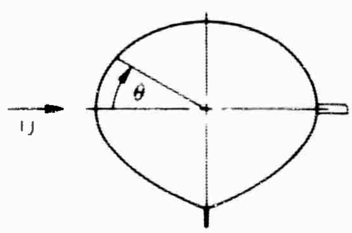


Table XIV. Surface Pressure Coefficients - Reynolds No. = 0.45 Million (Sheet 1)

Tap No.	α = -24.05 R = 0.46 x 10^6 q = 19.0 M = 0.292	α = -22.05 R = 0.45 x 10^6 q = 19.0 M = 0.293	α = -20.09 R = 0.45 x 10^6 q = 19.0 M = 0.294	α = -18.05 R = 0.45 x 10^6 q = 19.0 M = 0.294	α = -16.03 R = 0.45 x 10^6 q = 18.9 M = 0.294	α = -14.03 R = 0.45 x 10^6 q = 18.9 M = 0.295	α = -12.03 R = 0.45 x 10^6 q = 18.7 M = 0.294	α = -10.01 R = 0.45 x 10^6 q = 19.2 M = 0.299	α = -8.03 R = 0.45 x 10^6 q = 19.2 M = 0.299	α = -6.00 R = 0.45 x 10^6 q = 19.0 M = 0.298
2	-0.739	-0.760	-0.748	-0.759	-0.733	-0.730	-0.693	-0.677	-0.630	-0.602
3	-0.889	-0.894	-0.875	-0.824	-0.787	-0.765	-0.642	-0.620	-0.577	-0.552
4	-0.966	-0.925	-0.871	-0.797	-0.722	-0.634	-0.560	-0.487	-0.409	-0.348
5	-0.481	-0.410	-0.322	-0.209	-0.120	-0.045	0.071	0.156	0.229	0.304
6	0.526	0.588	0.645	0.714	0.763	0.787	0.850	0.871	0.901	0.915
7	0.929	0.895	0.864	0.841	0.798	0.737	0.687	0.610	0.540	0.458
8	0.333	0.235	0.162	0.087	0.007	-0.095	-0.179	-0.287	-0.394	-0.502
9	-0.139	-0.218	-0.276	-0.336	-0.394	-0.468	-0.541	-0.616	-0.691	-0.767
10	-0.292	-0.322	-0.372	-0.366	-0.425	-0.476	-0.506	-0.582	-0.615	-0.675
11	-0.543	-0.480	-0.449	-0.443	-0.425	-0.441	-0.502	-0.590	-0.664	-0.698
12	-0.412	-0.372	-0.376	-0.374	-0.332	-0.360	-0.385	-0.336	-0.413	-0.406
13	-0.259	-0.245	-0.234	-0.228	-0.220	-0.237	-0.342	-0.313	-0.379	-0.364
14	-0.174	-0.180	-0.196	-0.186	-0.247	-0.276	-0.424	-0.427	-0.463	-0.467
15	-0.439	-0.487	-0.533	-0.532	-0.556	-0.572	-0.506	-0.465	-0.474	-0.448
16	-0.997	-0.998	-0.987	-0.967	-0.953	-0.880	-0.825	-0.809	-0.793	-0.763
17	-1.058	-1.036	-0.994	-0.936	-0.876	-0.849	-0.751	-0.692	-0.637	-0.582
18	-0.739	-0.683	-0.603	-0.520	-0.440	-0.380	-0.280	-0.219	-0.151	-0.099
19	0.095	0.139	0.188	0.249	0.293	0.317	0.367	0.383	0.400	0.400
20	0.556	0.519	0.480	0.472	0.428	0.348	0.324	0.243	0.183	0.097
21	0.187	0.104	0.027	-0.032	-0.104	-0.214	-0.295	-0.389	-0.485	-0.586
22	-0.162	-0.238	-0.295	-0.340	-0.401	-0.491	-0.541	-0.616	-0.702	-0.771
23	-1.066	-1.06[illegible]	-1.086	-1.040	-1.073	-1.096	-1.059	-1.051	-1.055	-1.036
26	-1.193	-1.182	-1.182	-1.166	-1.138	-1.107	-1.071	-1.044	-1.029	-0.997
27	-1.135	-1.121	-1.090	-1.043	-0.992	-0.961	-0.903	-0.881	-0.843	-0.828
28	-0.751	-0.741	-0.706	-0.674	-0.644	-0.645	-0.619	-0.601	-0.607	-0.613
29	-0.285	-0.307	-0.338	-0.336	-0.378	-0.430	-0.463	-0.5[illegible]	-0.550	-0.625
30	-0.205	-0.261	-0.315	-0.363	-0.417	-0.499	-0.560	-0.6[illegible]	-0.698	-0.786
31	-0.259	-0.318	-0.364	-0.393	-0.444	-0.522	-0.568	-0.612	-0.691	-0.767
32	-0.997	-0.998	-0.994	-0.990	-0.992	-0.984	-0.970	-0.983	-1.006	-1.043
33	-1.027	-1.006	-1.010	-1.009	-0.999	-1.034	-0.997	-0.987	-1.051	-1.082
34	-1.166	-1.151	-1.109	-1.105	-1.092	-1.084	-1.090	-1.059	-1.089	-1.109
35	-0.916	-0.936	-0.9[illegible]0	-0.936	-0.934	-0.957	-0.974	-0.972	-1.021	-1.043
36	-0.469	-0.522	-0.556	-0.570	-0.606	-0.661	-0.701	-0.733	-0.916	-0.863
37	-0.727	-0.821	-0.875	-0.797	-0.960	-0.984	-0.958	-0.904	-0.945	-0.955
38	-0.447	-0.453	-0.483	-0.493	-0.533	-0.568	-0.638	-0.654	-0.831	-0.909
39	-0.666	-0.576	-0.572	-0.592	-0.552	-0.607	-0.693	-0.711	-0.763	-0.717
40	-0.731	-0.729	-0.706	-0.770	-0.737	-0.753	-0.704	-0.817	-0.658	-0.878
41	-0.670	-0.623	-0.691	-0.667	-0.663	-0.711	-0.724	-0.750	-0.854	-0.894
42	-0.458	-0.433	0.491	-0.482	-0.517	-0.56[illegible]	-0.510	-0.465	-0.512	-0.521
43	-0.228	-0.234	-0.268	-0.220	-0.239	-0.353	-0.373	-0.332	-0.413	-0.460
44	-0.539	-0.514	-0.499	-0.478	-0.444	-0.380	-0.389	-0.253	-0.185	-0.126
45	-0.516	-0.526	-0.441	-0.451	-0.421	-0.414	-0.541	-0.521	-0.561	-0.525
46	-0.654	-0.591	-0.572	-0.505	-0.490	-0.5[illegible]	-0.580	-0.677	-0.740	-0.832
47	0.289	-0.2[illegible]	-0.29[illegible]	-0.274	-0.232	-0.314	-0.264	-0.275	-0.235	-0.210

Table XIV. Surface Pressure Coefficients - Reynolds No. = 0.45 Million (Sheet 2)

Tap No.	α = -4.00 R = 0.45 x 10^6 q = 19.0 M = 0.299	α = -1.98 R = 0.45 x 10^6 q = 18.9 M = 0.299	α = 0.01 R = 0.44 x 10^6 q = 18.6 M = 0.294	α = 2.03 R = 0.44 x 10^6 q = 18.6 M = 0.293	α = 4.04 R = 0.45 x 10^6 q = 18.8 M = 0.294	α = 6.03 R = 0.45 x 10^6 q = 18.8 M = 0.294	α = 8.05 R = 0.45 x 10^6 q = 19.1 M = 0.295	α = 10.04 R = 0.45 x 10^6 q = 19.2 M = 0.295	α = 12.06 R = 0.45 x 10^6 q = 19.2 M = 0.295	α = 14.07 R = 0.46 x 10^6 q = 19.3 M = 0.295
2	-0.540	-0.547	-0.555	-0.569	-0.558	-0.536	-0.555	-1.312	-1.274	1.237
3	-0.478	-0.439	-0.417	-0.377	-0.326	-0.277	-0.303	-0.398	-0.337	-0.259
4	-0.244	-0.177	-0.090	-0.032	0.030	0.109	0.127	0.101	0.183	0.261
5	0.407	0.467	0.596	0.642	0.689	0.751	0.748	0.750	0.785	0.835
6	0.938	0.945	1.014	0.975	0.952	0.933	0.873	0.795	0.755	0.704
7	0.399	0.313	0.253	0.144	0.042	-0.057	-0.193	[illegible].304	-0.416	-0.514
8	-0.597	-0.674	-0.807	-0.913	-1.004	-1.077	-1.145	-1.251	-1.354	-1.376
9	-0.805	-0.863	-0.957	-1.015	-1.058	-1.077	-1.122	-1.123	-1.142	-1.147
10	-0.671	-0.712	-0.788	-0.819	-0.833	-0.857	-0.832	-0.685	-0.705	-0.664
11	-0.694	-0.747	-0.788	-0.819	-0.853	-0.791	-0.794	-0.[illegible]	-0.265	-0.282
12	-0.424	-0.385	-0.319	-0.09[illegible]	-0.210	-0.173	-0.181	-0.081	-0.054	-0.046
13	-0.390	-0.404	-0.415	-0.259	-0.477	-0.459	-0.532	-0.156	-0.224	-0.199
14	-0.455	-0.431	-0.460	-0.463	-0.512	-0.501	-0.516	-0.173	-0.179	-0.136
15	-0.440	-0.423	-0.445	-0.467	-0.473	-0.474	-0.593	-0.421	-0.453	-0.533
16	-0.694	-0.659	-0.654	-0.522	-0.566	-0.525	-0.524	0.625	-0.570	-0.488
17	-0.498	-0.427	-0.378	-0.267	-0.268	-0.209	-0.166	-0.183	-0.118	-0.035
18	-0.005	0.055	0.127	0.199	0.220	0.276	0.297	0.286	0.318	0.359
19	0.438	0.436	0.470	0.458	0.418	0.407	0.344	0.282	0.254	0.216
20	[illegible].064	-0.011	-0.090	-0.193	-0.283	-0.364	-0.497	-0.572	-0.675	-0.746
21	-0.640	-0.724	-0.847	-0.941	-1.019	-1.[illegible]	-1.190	-1.236	-1.311	-1.331
22	0.798	-0.847	.934	-0.992	-1.023	-1.058	-1.091	-1.085	-1.123	-1.128
23	-1.002	-0.963	-0.989	-0.678	-0.946	-0.937	-0.905	-1.081	-1.048	-0.960
26	-0.952	-0.901	-0.914	-0.757	-0.837	-0.803	-0.772	-0.832	-0.784	-0.709
27	-0.755	-0.728	-0.721	-0.616	-0.663	-0.629	-0.631	-0.643	-0.626	-0.574
28	-0.578	-0.570	-0.614	-0.584	-0.640	-0.67[illegible]	-0.695	-0.723	-0.758	-0.758
29	-0.644	-0.670	-0.772	-0.792	-0.88[illegible]	-0.931	-1.011	-1.046	-1.112	-1.140
30	-0.815	-0.863	-0.965	-1.00[illegible]	-1.[illegible]	-1.108	-1.160	-1.183	-1.228	-1.207
31	-0.782	-0.817	-0.898	-0.925	-0.969	-0.973	-1.019	-1.006	-1.048	-1.046
32	-1.005	-0.998	-1.052	-0.643	-1.038	-1.050	-1.065	-1.308	-1.308	-1.241
33	-1.063	-1.056	-1.115	-0.768	-1.112	-1.120	-0.874	-1.195	-1.198	-1.170
34	-1.079	-1.079	-1.123	-0.941	-1.147	-1.151	-1.18[illegible]	-1.202	-1.213	-1.207
35	-1.025	-1.021	-1.079	-0.992	-1.097	-1.101	-1.107	-1.085	-1.101	-1.076
36	-0.859	-0.878	-0.930	-0.925	-0.973	-0.96[illegible]	[illegible].992	-0.961	-0.961	-0.956
37	-0.925	-0.921	-0.969	-0.922	-0.930	-0.9[illegible]	-0.947	-1.106	-1.13[illegible]	-1.136
38	-0.886	-0.871	-0.918	-0.479	-0.942	-0.938	-0.962	-1.002	-1.022	-1.009
39	-0.690	-0.635	-0.591	-0.369	-0.609	-0.602	-0.[illegible]	-0.523	-0.608	-0.623
40	-0.846	-0.840	-0.870	-0.608	-0.487	-0.82[illegible]	-0.[illegible]3	-0.443	-0.446	-0.435
41	-0.877	-0.878	-0.902	-0.855	-0.903	-0.861	-0.875	0.708	-0.679	-0.656
42	-0.501	-0.481	-0.500	-0.518	-0.554	-0.521	-0.631	-0.6[illegible]	-0.705	-0.739
43	-0.474	-0.489	-0.551	-0.400	-0.558	-0.509	-0.513	-0.152	-0.254	-0.256
44	-0.078	-0.053	-0.033	-0.416	-0.070	-0.0[illegible]	-0.170	-0.0[illegible]2	-0.0[illegible]	-0.076
45	-0.424	-0.339	-0.236	-0.271	-0.152	-0.1[illegible]	-0.143	-0.017	-0.009	0.018
46	-0.809	-0.809	-0.851	-0.831	-0.864	-0.830	-0.836	-0.530	-0.495	-0.424
47	-0.140	-0.092	-0.118	0.003	-0.113	-0.145	-0.200	-0.013	-0.028	-0.061

Table XV. Surface Pressure Coefficients - Reynolds No. = 0.50 Million (Sheet 1)

Tap No.	α=-24.08 R=0.54 $\times 10^6$ q=22.6 M=0.294	α=-22.06 R=0.54 $\times 10^6$ q=22.7 M=0.295	α=-20.06 R=0.54 $\times 10^6$ q=22.6 M=0.295	α=-18.04 R=0.53 $\times 10^6$ q=22.7 M=0.297	α=-16.04 R=0.53 $\times 10^6$ q=22.7 M=0.298	α=-14.03 R=0.53 $\times 10^6$ q=22.7 M=0.299	α=-12.02 R=0.53 $\times 10^6$ q=22.7 M=0.299	α=-10.00 R=0.53 $\times 10^6$ q=22.6 M=0.299	α=-8.02 R=0.53 $\times 10^6$ q=22.7 M=0.301	α=-6.02 R=0.53 $\times 10^6$ q=22.5 M=0.300	α=-3.98 R=0.53 $\times 10^6$ q=22.7 M=0.302	α=-1.99 R=0.52 $\times 10^6$ q=22.5 M=0.301
2	-0.758	-0.748	-0.688	-0.701	-0.735	-0.611	-0.699	-0.674	-0.609	-0.497	-0.571	-0.567
3	-0.910	-0.692	-0.863	-0.630	0.809	-0.753	-0.709	-0.671	-0.609	-0.591	-0.526	-0.473
4	-0.981	-0.915	-0.863	-0.798	-0.729	-0.653	-0.573	-0.513	-0.417	-0.342	-0.271	-0.184
5	-0.494	-0.405	-0.310	-0.208	-0.127	-0.027	0.060	0.144	0.244	0.316	0.392	0.468
6	0.516	0.579	0.657	0.716	0.770	0.824	0.662	0.884	0.917	0.935	0.926	0.945
7	0.912	0.887	0.873	0.835	0.795	0.759	0.694	0.619	0.564	0.482	0.395	0.316
8	0.316	0.233	0.175	0.098	0.001	-0.085	-0.184	-0.277	-0.375	-0.487	-0.593	-0.677
9	-0.158	-0.225	-0.284	-0.343	-0.412	-0.483	-0.538	-0.616	-0.686	-0.753	-0.831	-0.875
10	-0.326	-0.373	-0.388	-0.411	-0.447	-0.480	-0.512	-0.577	-0.612	-0.659	-0.709	-0.733
11	-0.694	-0.623	-0.598	-0.550	-0.489	-0.525	-0.554	-0.610	-0.647	-0.672	-0.748	-0.775
12	-0.381	-0.395	-0.355	-0.321	-0.316	-0.290	-0.290	-0.286	-0.266	-0.277	-0.358	-0.311
13	-0.213	-0.203	-0.187	-0.176	-0.191	-0.149	-0.133	-0.180	-0.285	-0.147	-0.313	-0.343
14	-0.113	-0.091	-0.122	-0.166	-0.178	-0.204	-0.271	-0.315	-0.311	-0.381	-0.442	-0.454
15	-0.371	-0.415	-0.465	-0.498	-0.540	-0.502	-0.535	-0.535	-0.481	-0.449	-0.439	-0.444
16	-1.006	-0.998	-0.979	-0.975	-0.950	-0.913	-0.873	-0.858	-0.798	-0.756	-0.699	-0.668
17	-1.090	-1.037	-0.992	-0.936	-0.889	-0.826	-0.766	-0.706	-0.631	-0.575	-0.516	-0.444
18	-0.748	-0.671	-0.588	-0.511	-0.441	-0.348	-0.281	-0.215	-0.138	-0.076	-0.010	0.053
19	0.087	0.140	0.201	0.256	0.302	0.342	0.373	0.392	0.420	0.433	0.427	0.439
20	0.538	0.502	0.495	0.468	0.417	0.384	0.331	0.260	0.209	0.141	0.041	-0.022
21	0.164	0.092	0.029	-0.044	-0.117	-0.204	-0.287	-0.387	-0.455	-0.568	-0.658	-0.742
22	-0.191	-0.258	-0.313	-0.366	-0.425	-0.486	-0.544	-0.632	-0.670	-0.750	-0.796	-0.853
23	-1.097	-1.114	-1.128	-1.113	-1.129	-1.038	-1.079	-1.098	-1.035	-1.032	-1.021	-0.992
26	-1.219	-1.200	-1.202	-1.161	-1.152	-1.070	-1.085	-1.072	-1.003	-0.990	-0.957	-0.918
27	-1.161	-1.130	-1.089	-1.026	-1.004	-0.968	-0.918	-0.862	-0.811	-0.812	-0.767	-0.736
28	-0.761	-0.758	-0.701	-0.672	-0.652	-0.624	-0.612	-0.600	-0.561	-0.585	-0.593	-0.590
29	-0.303	-0.325	-0.346	-0.347	-0.374	-0.412	-0.451	-0.500	-0.526	-0.591	-0.642	-0.687
30	-0.220	-0.290	-0.336	-0.376	-0.434	-0.493	-0.551	[illegible]	-0.667	-0.753	-0.828	-0.875
31	-0.287	-0.347	-0.381	-0.417	-0.482	-0.525	-0.573	-0.65[illegible]	-0.667	-0.747	-0.796	-0.840
32	-1.032	-0.992	-1.024	-1.023	-1.020	-1.025	-1.021	-1.039	-0.997	-1.016	-1.025	-1.034
33	-1.051	-1.040	-1.060	-1.023	-1.052	-0.935	-1.034	-1.052	-1.038	-1.071	-1.079	-1.083
34	-1.206	-1.175	-1.163	-1.142	-1.113	-1.109	-1.098	-1.094	-1.067	-1.100	-1.099	-1.099
35	-0.987	-0.973	-0.969	-0.962	-0.953	-0.968	-0.966	-0.991	-0.971	-1.022	-1.041	-1.047
36	-0.532	-0.569	-0.604	-0.611	-0.649	-0.675	-0.709	-0.768	-0.769	-0.837	-0.877	-0.888
37	-0.694	-0.780	-0.869	-0.846	-0.937	-0.849	-0.882	-0.978	-0.907	-0.941	-0.947	-0.934
38	-0.416	-0.431	-0.452	-0.463	-0.482	-0.541	-0.573	-0.597	-0.750	-0.899	-0.925	-0.914
39	-0.629	-0.710	-0.704	-0.608	-0.585	-0.640	-0.657	-0.690	-0.667	-0.627	-0.635	-0.613
40	-0.855	-0.876	-0.843	-0.798	-0.777	-0.797	-0.811	-0.836	-0.814	-0.857	-0.854	-0.856
41	-0.752	-0.771	-0.769	-0.740	-0.726	-0.743	-0.776	-0.813	-0.814	-0.876	-0.893	-0.905
42	-0.361	-0.399	-0.439	-0.475	-0.482	-0.525	-0.528	-0.545	-0.484	-0.497	-0.510	-0.499
43	-0.136	-0.126	-0.165	-0.134	-0.146	-0.172	-0.232	-0.286	-0.304	[illegible]	-0.445	-0.470
44	-0.510	-0.485	-0.465	-0.446	-0.393	[illegible]	-0.293	-0.206	-0.115	-0.056	-0.014	-0.006
45	-0.543	-0.546	-0.472	-0.414	-0.358	-0.354	-0.416	-0.458	-0.407	-0.351	-0.345	-0.278
46	-0.781	-0.767	-0.733	-0.624	-0.588	-0.589	-0.622	-0.716	-0.705	-0.782	-0.838	-0.823
47	-0.226	-0.216	-0.242	-0.221	-0.204	-0.155	-0.149	-0.125	-0.096	-0.073	-0.068	-0.025

Table XV. Surface Pressure Coefficients - Reynol : No. = 0.50 Million (Sheet 2)

Tap No.	α=0.00 R=0.52 x 10^6 q=22.[illegible] M=0.302	α=2.03 R=0.52 x 10^6 q=22.1 M=0.294	α=4.03 R=0.52 x 10^6 q=22.1 M=0.294	α=6.03 R=0.53 x 10^6 q=22.1 M=0.294	α=8.03 R=0.53 x 10^6 q=22.0 M=0.292	α=10.06 R=0.53 x 10^6 q=22.1 M=0.292	α=12.04 R=0.53 x 10^6 q=22.3 M=0.293	α=14.06 R=0.53 x 10^6 q=21.8 M=0.289	α=16.07 R=0.53 x 10^6 q=22.0 M=0.290	α=18.07 R=0.53 x 10^6 q=21.9 M=0.288	α=20.09 R=0.53 x 10^6 q=22.0 M=0.289	α=21.07 R=0.54 x 10^6 q=22.3 M=0.289
2	-0.524	-0.575	-0.540	-0.545	-1.315	-1.288	-1.281	-1.240	-1.210	-1.195	-1.117	-1.109
3	-0.416	-0.391	-0.323	-0.299	-0.458	-0.359	-0.312	-0.256	-0.190	-0.141	-0.058	-0.041
4	-0.127	-0.038	0.029	0.088	0.037	0.142	0.199	0.278	0.332	0.384	0.457	0.464
5	0.529	0.620	0.680	0.730	0.688	0.772	0.807	0.839	0.851	0.872	0.900	0.895
6	0.935	0.959	0.946	0.910	0.819	0.825	0.771	0.716	[illegible]	0.588	0.523	0.471
7	0.230	0.133	0.035	-0.066	-0.186	-0.261	-0.380	-0.494	-0.606	-0.719	-0.815	-0.889
8	-0.761	-0.904	-0.988	-1.085	-1.155	-1.202	-1.287	-1.347	-1.427	-1.509	-1.534	-1.575
9	-0.923	-1.019	-1.027	-1.069	-1.060	-1.055	-1.092	-1.131	-1.174	-1.228	-1.261	-1.287
10	-0.761	-0.805	-0.810	-0.853	-0.680	-0.635	-0.653	-0.637	[illegible]	-0.633	-0.612	-0.620
11	-0.793	-0.858	-0.794	-0.807	-0.274	-0.166	-0.198	-0.136	-0.111	-0.145	-0.179	-0.225
12	-0.257	-0.154	-0.113	-0.112	-0.189	-0.097	-0.058	0.000	-0.003	-0.003	0.021	0.008
13	[illegible]	-0.381	-0.254	-0.502	-0.137	-0.143	-0.191	-0.199	-0.173	-0.211	-0.261	-0.267
14	-0.433	-0.437	-0.432	-0.446	-0.186	-0.136	-0.198	-0.166	-0.157	-0.155	-0.150	-0.177
15	-0.472	-0.496	-0.501	-0.502	-0.500	-0.468	-0.484	-0.571	-0.643	[illegible]	-0.681	-0.733
16	-0.628	-0.608	-0.563	-0.515	-0.677	-0.536	-0.549	-0.488	-0.429	[illegible]	-0.307	-0.283
17	-0.381	-0.321	-0.261	-0.233	-0.251	-0.153	-0.100	-0.033	0.017	0.077	0.139	0.157
18	0.107	0.166	0.223	0.252	0.230	0.306	0.342	0.371	0.388	0.410	0.434	0.432
19	0.428	0.429	0.417	0.406	0.315	0.320	0.270	0.229	0.161	0.110	0.054	0.01[illegible]
20	-0.098	-0.193	-0.287	-0.364	-0.480	-0.523	-0.643	-0.733	-0.830	-0.937	-1.019	-1.076
21	-0.806	-0.937	-1.011	-1.092	-1.145	-1.176	-1.261	-1.320	-1.371	-1.436	-1.468	-1.497
22	-0.904	-0.983	-1.007	-1.030	-1.030	-1.029	-1.069	-1.108	-1.151	-1.195	-1.229	-1.264
23	-0.969	-0.960	-0.955	-1.108	-1.112	-1.038	-1.004	-0.959	-0.912	-0.858	-0.799	-0.785
26	-0.901	-0.871	-0.836	-0.751	-0.863	-0.799	-0.760	-0.717	-0.672	-0.630	-0.573	-0.565
27	-0.706	-0.693	-0.659	-0.636	-0.660	-0.612	-0.598	-0.571	-0.551	-0.544	-0.517	-0.523
28	-0.562	-0.624	-0.636	-0.633	-0.690	-0.684	-0.718	-0.743	-0.780	-0.828	-0.855	-0.892
29	-0.732	-0.822	-0.876	-0.908	-0.971	-1.006	-1.076	-1.128	-1.177	-1.244	-1.291	-1.326
30	-0.923	-1.019	-1.037	-1.089	-1.105	-1.137	-1.173	-1.197	-1.223	-1.254	-1.265	-1.293
31	-0.868	-0.937	-0.955	-0.961	-0.952	-0.953	-0.991	-1.028	-1.066	-1.023	-0.874	-0.843
32	-1.024	-1.032	-1.060	-1.308	-1.331	-1.288	-1.274	-1.264	-1.207	-1.188	-1.153	-1.141
33	-1.086	-1.118	-1.123	-1.128	-1.181	-1.170	-1.173	-1.168	-1.145	-1.158	-1.134	-1.141
34	-1.089	-1.135	-1.136	-1.144	-1.161	-1.160	-1.186	-1.194	-1.220	-1.248	-1.288	-1.303
35	-1.050	-1.085	-1.096	-1.036	-1.069	-1.058	-1.056	-1.075	-1.089	-1.099	-1.117	-1.131
36	-0.904	-0.954	-0.961	-0.918	-0.906	-0.888	-0.907	-0.945	-0.872	-0.732	-0.727	-0.740
37	-0.511	-0.950	-0.938	-0.833	-1.148	-1.143	-1.170	-1.151	-1.168	-1.172	-1.157	-1.151
38	0.364	-0.943	-0.942	-0.951	-0.994	-0.993	-1.004	-0.998	-1.036	-1.059	-1.124	-1.154
39	-0.358	-0.565	-0.573	-0.561	-0.513	-0.491	-0.555	-0.600	-0.577	-0.614	-0.806	-0.873
40	-0.725	-0.871	-0.876	-0.669	-0.461	-0.428	-0.406	-0.385	-0.410	-0.386	-0.415	-0.413
41	-0.836	-0.924	-0.902	-0.886	-0.719	-0.619	-0.581	-0.581	-0.551	-0.528	-0.517	-0.520
42	-0.507	-0.499	-0.534	-0.512	-0.654	-0.638	-0.728	-0.776	-0.803	-0.841	-0.976	-0.986
43	-0.368	-0.526	-0.544	-0.469	-0.134	-0.146	-0.221	-0.269	-0.344	-0.264	-0.520	-0.542
44	-0.209	-0.015	-0.037	-0.096	0.004	0.011	-0.016	-0.030	-0.078	-0.237	-0.166	-0.206
45	-0.105	-0.150	-0.136	-0.109	-0.049	0.034	0.049	0.043	0.040	0.040	0.037	0.018
46	-0.790	-0.871	-0.876	-0.764	-0.458	-0.415	-0.308	-0.315	-0.305	-0.313	-0.307	-0.313
47	0.016	-0.038	-0.067	-0.122	0.086	0.100	0.082	0.030	0.001	-0.065	-0.124	-0.138

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Table XVI. Surface Pressure Coefficients - Reynolds No. = 0.78 Million

Tap No.	α = -6.01 R = 0.78 x 10^6 q = 34.3 M = 0.301	α = -4.00 R = 0.78 x 10^6 q = 34.8 M = 0.304	α = -2.00 R = 0.78 x 10^6 q = 34.7 M = 0.304	α = 0.00 R = 0.78 x 10^6 q = 34.6 M = 0.305	α = 2.00 R = 0.78 x 10^6 q = 34.5 M = 0.305
2	-0.627	-0.574	-0.661	-0.596	-0.546
3	-0.621	-0.537	-0.497	-0.459	-0.444
4	-0.360	-0.273	-0.199	-0.139	-0.064
5	0.327	0.411	0.487	0.541	0.596
6	0.953	0.965	0.981	0.964	0.960
7	0.497	0.425	0.350	0.255	0.171
8	-0.485	-0.543	-0.659	-0.754	-0.842
9	-0.767	-0.792	-0.859	-0.919	-0.952
10	-0.682	-0.683	-0.725	-0.756	-0.751
11	-0.782	-0.769	-0.840	-0.864	-0.793
12	-0.039	0.007	0.098	0.048	-0.066
13	-0.023	0.066	-0.070	-0.211	-0.131
14	-0.179	-0.242	-0.152	-0.196	-0.254
15	-0.449	-0.432	-0.455	-0.483	-0.499
16	-0.805	-0.710	-0.670	-0.598	-0.571
17	-0.578	-0.480	-0.432	-0.348	-0.315
18	-0.059	0.043	0.077	0.128	0.192
19	0.448	0.475	0.477	0.459	0.465
20	0.149	0.103	0.018	-0.059	-0.138
21	-0.557	-0.632	-0.714	-0.796	-0.865
22	-0.758	-0.761	-0.847	-0.891	-0.929
23	-1.079	-1.018	-1.002	-0.992	-0.952
26	-1.006	-0.903	-0.859	-0.876	-0.808
27	-0.792	-0.717	-0.678	-0.683	-0.618
28	-0.565	-0.530	-0.533	-0.567	-0.550
29	-0.582	-0.591	-0.649	-0.714	-0.745
30	-0.748	-0.767	-0.842	-0.904	-0.929
31	-0.734	-0.750	[illegible]	-0.849	-0.851
32	-1.085	-1.045	-0.842	-0.784	-0.832
33	-1.096	-1.060	-0.954	-0.954	-0.965
34	-1.087	-1.039	-1.076	-1.081	-1.041
35	-1.021	-0.976	-1.019	-1.030	-0.999
36	-0.839	-0.827	-0.859	-0.893	-0.868
37	-0.799	-0.903	-0.975	-0.904	[illegible]
38	-0.621	-0.738	-0.876	-0.784	-0.554
39	[illegible]	-0.491	-0.449	-0.493	-0.417
40	-0.845	-0.800	-0.830	-0.822	-0.713
41	-0.890	-0.848	-0.893	-0.839	-0.825
42	-0.476	-0.413	-0.483	-0.474	-0.529
43	-0.209	-0.223	-0.239	-0.228	-0.205
44	0.092	0.153	0.083	-0.108	-0.140
45	-0.158	-0.029	-0.024	-0.063	0.004
46	-0.881	-0.858	-0.897	-0.874	-0.787
47	0.088	[illegible]	0.153	0.145	0.095

Table XVII. Surface Pressure Coefficients - Reynolds No. = 1 Million (Sheet 1)

Tap No.	α = -14.53 R = 1.07 x 10^6 q = 46.4 M = 0.298	α = -14.04 R = 1.07 x 10^6 q = 46.5 M = 0.299	α = -12.02 R = 1.07 x 10^6 q = 46.6 M = 0.300	α = -10.01 R = 1.07 x 10^6 q = 46.5 M = 0.300	α = -8.03 R = 1.06 x 10^6 q = 46.5 M = 0.300	α = -6.01 R = 1.06 x 10^6 q = 46.5 M = 0.300	α = -4.00 R = 1.06 x 10^6 q = 46.7 M = 0.302	α = -1.99 R = 1.06 x 10^6 q = 46.5 M = 0.302
2	-0.688	-0.736	-0.725	-0.722	-0.698	-0.756	-0.770	-0.775
3	-0.766	-0.766	-0.728	-0.687	-0.652	-0.617	-0.573	-0.536
4	-0.655	-0.636	-0.563	-0.499	-0.413	-0.360	-0.278	-0.212
5	-0.020	0.002	0.084	0.166	0.258	0.328	0.413	0.476
6	0.842	0.849	0.887	0.915	0.948	0.957	0.981	0.976
7	0.778	0.762	0.705	0.637	0.582	0.499	0.431	0.346
8	-0.092	-0.118	-0.204	-0.297	-0.381	-0.486	-0.565	-0.668
9	-0.522	-0.535	-0.602	-0.660	-0.705	-0.775	-0.815	-0.874
10	-0.597	-0.603	-0.633	-0.663	-0.676	-0.712	-0.716	-0.739
11	-1.115	-1.098	-1.074	-1.028	-0.979	-0.965	-0.917	-0.916
12	0.027	0.052	0.069	0.093	0.119	0.104	0.144	0.102
13	0.138	0.142	0.268	0.220	0.183	0.129	0.072	0.042
14	-0.045	-0.007	-0.033	-0.049	-0.145	-0.197	-0.230	-0.133
15	-0.194	-0.220	-0.197	-0.233	-0.270	-0.316	-0.302	-0.400
16	-0.884	-0.867	-0.860	-0.825	-0.801	-0.784	-0.722	-0.682
17	-0.813	-0.802	-0.742	-0.688	-0.615	-0.572	-0.479	-0.445
18	-0.353	-0.324	-0.258	-0.181	-0.101	-0.055	0.028	0.078
19	0.360	0.367	0.405	0.427	0.459	0.460	0.483	0.479
20	0.404	0.394	0.341	0.276	0.231	0.152	0.097	0.017
21	-0.206	-0.224	-0.305	-0.392	-0.463	-0.562	-0.630	-0.719
22	-0.532	-0.549	-0.607	-0.662	-0.701	-0.762	-0.798	-0.847
23	-1.093	-1.109	-1.095	-1.072	-1.069	-1.077	-0.969	-1.065
26	-1.093	-1.098	-1.078	-1.016	-0.994	-0.993	-0.915	-0.894
27	-0.931	-0.933	-0.895	-0.860	-0.807	-0.784	-0.710	-0.691
28	-0.613	-0.617	-0.583	-0.570	-0.552	-0.561	-0.529	-0.546
29	-0.410	-0.416	-0.454	-0.495	-0.520	-0.578	-0.607	-0.655
30	-0.510	-0.525	-0.583	-0.640	-0.682	-0.750	-0.786	-0.846
31	-0.585	-0.594	-0.638	-0.687	-0.709	-0.764	-0.780	-0.822
32	-0.982	-1.004	-1.022	-1.051	-0.943	-1.004	-1.052	-0.927
33	-1.037	-1.023	-1.018	-1.055	-0.999	-1.066	-1.077	-1.035
34	-1.123	-1.100	-1.102	-1.094	-1.068	-1.071	-1.061	-1.037
35	-1.014	-1.009	-1.005	-1.008	-0.990	-1.013	-1.005	-1.005
36	-0.751	-0.761	-0.783	-0.811	-0.815	-0.851	-0.853	-0.871
37	-0.560	-0.524	-0.574	-0.582	-0.730	-0.531	-0.627	-0.885
38	-0.421	-0.402	-0.401	-0.395	-0.443	-0.483	-0.446	-0.585
39	-0.582	-0.575	-0.535	-0.540	-0.506	-0.512	-0.485	-0.449
40	-0.985	-1.001	-0.948	-0.905	-0.869	-0.857	-0.809	-0.818
41	-0.942	-0.947	-0.944	-0.942	-0.924	-0.935	-0.901	-0.901
42	-0.264	-0.262	-0.239	-0.270	-0.281	-0.264	-0.442	-0.511
43	0.058	0.002	-0.037	-0.047	-0.044	-0.140	-0.271	-0.187
44	0.173	0.155	0.156	0.140	0.164	0.152	0.173	0.143
45	-0.416	-0.430	-0.317	-0.258	-0.225	-0.202	-0.144	-0.119
46	-1.084	-1.072	-1.050	-1.027	-0.994	-0.979	-0.937	-0.918
47	0.121	0.113	0.146	0.162	0.200	0.277	0.226	0.216

Table XVII. Surface Pressure Coefficients - Reynolds No. = 1 Million (Sheet 2)

Tap No.	α = 0.00 R = 1.05 x 10^6 q = 44.9 M = 0.296	α = 2.03 R = 1.05 x 10^8 q = 44.9 M = 0.296	α = 3.07 R = 1.05 x 10^6 q = 46.8 M = 0.304	α = 4.02 R = 1.05 x 10^6 q = 44.9 M = 0.295	α = 6.03 R = 1.06 x 10^6 q = 45.2 M = 0.295	α = 8.05 R = 1.06 x 10^6 q = 45.2 M = 0.296	α = 9.04 R = 1.06 x 10^6 q = 45.2 M = 0.295
2	-0.911	-0.995	-0.950	-1.339	-1.353	-1.349	-1.313
3	-0.531	-0.523	-0.502	-0.511	-0.428	-0.381	-0.351
4	-0.178	-0.100	-0.082	-0.059	0.037	0.110	0.147
5	0.520	0.596	0.824	0.634	0.713	0.759	0.780
6	0.953	0.964	0.960	0.936	0.936	0.903	0.887
7	0.233	0.165	0.135	0.072	-0.001	-0.102	-0.157
8	-0.784	-0.846	-0.855	-0.924	-0.978	-1.065	-1.099
9	-0.943	-0.943	-0.924	-0.984	-0.965	-0.997	-1.002
10	-0.768	-0.721	-0.680	-0.861	-0.627	-0.631	-0.623
11	-0.876	-0.521	-0.404	-0.322	-0.366	-0.245	-0.219
12	-0.027	-0.093	-0.084	-0.133	-0.033	-0.038	-0.052
13	-0.046	-0.015	-0.017	-0.054	-0.087	-0.091	-0.098
14	-0.184	-0.114	-0.045	-0.101	-0.084	-0.101	-0.113
15	-0.412	-0.379	-0.305	-0.340	-0.363	-0.414	-0.393
16	-0.720	-0.720	-0.619	-0.729	-0.651	-0.610	-0.577
17	-0.428	-0.361	-0.316	-0.330	-0.243	-0.183	-0.151
18	0.088	0.163	0.208	0.194	0.265	0.306	0.327
19	0.438	0.445	0.480	0.415	0.423	0.393	0.376
20	-0.103	-0.149	-0.160	-0.239	-0.304	-0.384	-0.431
21	-0.834	-0.867	-0.889	-0.950	-0.989	-1.061	-1.090
22	-0.924	-0.904	-0.896	-0.934	-0.933	-0.960	-0.966
23	-1.020	-1.050	-1.039	-1.140	-1.088	-1.050	-1.031
26	-0.908	-0.922	-0.885	-0.910	-0.841	-0.803	-0.779
27	-0.701	-0.677	-0.621	-0.673	-0.624	-0.597	-0.581
28	-0.598	-0.595	-0.558	-0.617	-0.611	-0.623	-0.633
29	-0.759	-0.765	-0.757	-0.826	-0.855	-0.905	-0.931
30	-0.932	-0.938	-0.924	-0.983	-0.999	-1.045	-1.042
31	-0.870	-0.848	-0.817	-0.868	-0.852	-0.876	-0.886
32	-1.133		-1.047	-1.307	-1.292	-1.274	-1.265
33	-1.080	-1.067	-1.081	-1.166	-1.145	-1.142	-1.137
34	-1.099	-1.076	-1.050	-1.105	-1.106	-1.115	-1.117
35	-1.043	-1.012	-0.983	-1.019	-1.015	-1.021	-1.017
36	-0.913	-0.867	-0.829	-0.865	-0.841	-0.828	-0.830
37	-1.006	-0.970	-1.031	-1.112	-1.121	-1.124	-1.118
38	-0.863	-0.830	-0.862	-0.966	-0.946	-0.962	-0.956
39	-0.483	-0.470	-0.453	-0.530	-0.508	-0.505	-0.499
40	-0.810	-0.811	-0.513	-0.524	-0.497	-0.472	-0.445
41	-0.898	-0.803	-0.736	-0.780	-0.718	-0.869	-0.633
42	-0.525	-0.492	-0.533	-0.529	-0.611	-0.647	-0.671
43	-0.191	-0.157	0.000	-0.085	-0.105	-0.128	-0.133
44	0.006	0.057	0.023	0.075	0.095	0.078	0.072
45	-0.010	-0.015	0.002	-0.027	0.002	0.016	0.039
46	-0.858	-0.891	-0.624	-0.482	-0.543	-0.438	-0.442
47	0.108	0.150	0.205	0.151	0.106	0.102	0.113

Table XVIII. Surface Pressure Coefficients - Reynolds No. = 5 Million (Sheet 1)

Tap No.	α = -24.63 R = 5.00 x 10^6 q = 215.2 M = 0.290	α = -19.99 R = 5.00 x 10^6 q = 215.1 M = 0.290	α = -15.06 R = 5.00 x 10^6 q = 215.0 M = 0.290	α = -10.01 R = 5.01 x 10^6 q = 215.7 M = 0.291	α = -4.99 R = 5.03 x 10^6 q = 215.7 M = 0.290	α = 0.04 R = 5.05 x 10^6 q = 212.9 M = 0.289	α = 4.02 R = 5.03 x 10^6 q = 215.0 M = 0.290
2	-0.495	-0.797	-1.134	-1.363	-1.575	-1.693	-1.654
3	-0.866	-0.929	-0.900	-0.874	-0.821	-0.723	-0.618
4	-1.008	-0.933	-0.835	-0.627	-0.462	-0.267	-0.117
5	-0.543	-0.341	-0.126	0.116	0.317	0.514	0.638
6	0.529	0.696	0.843	0.944	0.998	1.008	0.987
7	0.986	0.927	0.814	0.666	0.480	0.256	0.091
8	0.326	0.125	-0.100	-0.338	-0.583	-0.809	-0.963
9	-0.235	-0.394	-0.556	-0.693	-0.845	-0.947	-0.989
10	-0.486	-0.573	-0.660	-0.678	-0.717	-0.731	-0.690
11	-1.409	-1.288	-1.144	-0.849	-0.614	-0.304	-0.292
12	-0.839	-0.487	-0.235	-0.162	-0.106	-0.224	-0.440
13	-0.308	-0.182	-0.119	-0.059	0.002	-0.146	-0.276
14	-0.229	-0.239	-0.231	-0.277	-0.167	-0.134	-0.190
15	-0.397	-0.409	-0.308	-0.298	-0.330	-0.561	-0.683
16	-0.865	-0.991	-0.976	-1.004	-1.007	-0.949	-0.828
17	-1.034	-1.001	-0.919	-0.807	-0.683	-0.542	-0.391
18	-0.789	-0.618	-0.478	-0.253	-0.092	0.056	0.196
19	0.087	0.229	0.324	0.420	0.456	0.443	0.460
20	0.593	0.531	0.415	0.282	0.105	-0.114	-0.224
21	0.172	-0.011	-0.225	-0.429	-0.653	-0.866	-0.945
22	-0.265	-0.430	-0.580	-0.711	-0.839	-0.935	-0.968
23	-0.782	-1.017	-1.042	-1.210	-1.329	-1.375	-1.284
26	-1.028	-1.111	-1.146	-1.106	-1.091	-1.097	-0.978
27	-1.092	-1.072	-1.039	-0.969	-0.880	-0.841	-0.705
28	-0.824	-0.733	-0.723	-0.643	-0.634	-0.687	-0.621
29	-0.313	-0.364	-0.457	-0.546	-0.667	-0.809	-0.788
30	-0.253	-0.391	-0.559	-0.682	-0.821	-0.978	-0.943
31	-0.397	-0.523	-0.641	-0.725	-0.822	-0.889	-0.848
32	-0.345	-0.569	-0.492	-0.907	-1.296	-1.525	-1.460
33	-0.258	-0.497	-1.049	-1.038	-1.119	-1.312	-1.243
34	-1.074	-1.044	-1.170	-1.131	-1.123	-1.184	-1.005
35	-1.030	-1.00[illegible]	-1.097	-1.080	-1.074	-1.132	-0.848
36	-0.635	-0.725	-0.813	-0.848	-0.886	-0.912	-0.703
37	-0.247	-0.356	-0.258	-0.253	-0.837	-1.223	-1.264
38	-0.261	-0.240	-0.270	-0.250	-0.264	-0.839	-0.836
39	-0.210	-0.184	-0.381	-0.384	-0.318	-0.393	-0.171
40	-1.148	-1.012	-1.050	-0.937	-0.669	-0.650	-0.139
41	-1.002	-1.020	-0.980	-0.938	-0.890	-0.852	-0.397
42	-0.370	-0.364	-0.382	-0.292	-0.319	-0.785	-0.852
43	-0.318	-0.374	-0.303	-0.320	-0.324	-0.148	-0.188
44	-0.395	-0.343	-0.201	-0.108	-0.217	-0.173	-0.403
45	-0.989	-0.634	-0.191	-0.095	-0.088	-0.239	-0.214
46	-1.252	-1.223	-1.109	-0.888	-0.788	-0.668	-0.127
47	-0.231	-0.198	-0.199	-0.186	-0.058	0.003	0.070

Table XVIII. Surface Pressure Coefficients - Reynolds No. = 5 Million (Sheet 2)

Tap No.	α = 5.02 R = 5.05 x 10^6 q = 213.7 M = 0.290	α = 8.52 R = 5.01 x 10^6 q = 212.9 M = 0.288	α = 10.03 R = 5.02 x 10^6 q = 214.3 M = 0.289	α = 12.54 R = 5.02 x 10^6 q = 215.0 M = 0.289	α = 13.96 R = 5.02 x 10^6 q = 215.0 M = 0.289	α = 15.15 R = 5.02 x 10^6 q = 215.0 M = 0.289	α = 20.06 R = 5.02 x 10^6 q = 215.7 M = 0.290	α = 24.75 R = 5.00 x 10^6 q = 214.5 M = 0.288
2	-1.645	-1.547	-1.511	-1.504	-1.473	-1.443	-1.235	-1.139
3	-0.567	-0.451	-0.392	-0.319	-0.266	-0.232	-0.035	0.108
4	-0.031	0.082	0.148	0.240	0.293	0.332	0.521	0.645
5	0.683	0.762	0.819	0.875	0.904	0.921	0.988	1.008
6	0.977	0.923	0.894	0.834	0.801	0.772	0.604	0.452
7	0.027	-0.184	-0.258	-0.302	-0.471	-0.526	-0.786	-0.892
8	-0.997	-1.193	-1.254	-1.324	-1.373	-1.395	-1.526	-1.291
9	-0.976	-1.095	-1.104	-1.091	-1.087	-1.062	-1.079	-0.339
10	-0.693	-0.746	-0.722	-0.661	-0.649	-0.578	-0.519	-0.315
11	-0.312	-0.455	-0.395	-0.291	-0.239	-0.029	-0.215	-0.373
12	-0.479	-0.354	-0.278	-0.291	-0.243	-0.102	-0.201	-0.157
13	-0.228	-0.151	-0.128	-0.206	-0.233	-0.243	-0.267	-0.360
14	-0.173	-0.118	-0.130	-0.174	-0.183	-0.205	-0.150	-0.743
15	-0.696	-0.617	-0.616	-0.870	-0.803	-0.920	-0.829	-0.989
16	-0.798	-0.687	-0.625	-0.576	-0.530	-0.502	-0.300	-0.165
17	-0.345	-0.216	-0.153	-0.094	-0.034	0.002	0.170	0.305
18	0.231	0.313	0.353	0.389	0.415	0.435	0.492	0.536
19	0.444	0.388	0.375	0.310	0.276	0.252	0.096	0.002
20	-0.275	-0.444	-0.513	-0.637	-0.712	-0.771	-1.026	-1.115
21	-0.980	-1.154	-1.200	-1.248	-1.329	-1.333	-1.457	-1.037
22	-0.934	-1.029	-1.029	-0.997	-1.040	-0.997	-1.018	-0.304
23	-1.258	-1.167	-1.108	-1.087	-1.059	-1.032	-0.863	-0.705
26	-0.943	-0.857	-0.807	-0.771	-0.750	-0.727	-0.588	-0.463
27	-0.694	-0.644	-0.611	-0.601	-0.590	-0.581	-0.543	-0.470
28	-0.617	-0.665	-0.681	-0.729	-0.770	-0.772	-0.893	-0.881
29	-0.840	-0.962	-1.000	-1.048	-1.090	-1.119	-1.299	-1.209
30	-0.938	-1.070	-1.121	-1.111	-1.220	-1.182	-1.247	-0.690
31	-0.826	-0.925	-0.928	-0.873	-0.941	-0.936	-0.862	-0.298
32	-1.476	-1.409	-1.373	-1.408	-1.370	-1.366	-1.238	-1.164
33	-1.232	-1.201	-1.187	-1.241	-1.262	-1.229	-1.208	-1.153
34	-1.072	-1.019	-1.061	-1.131	-1.298	-1.155	-1.338	-1.231
35	-0.868	-0.867	-0.863	-0.904	-1.125	-0.875	-1.087	-0.558
36	-0.713	-0.776	-0.753	-0.743	-0.854	-0.683	-0.740	-0.299
37	-1.282	-1.245	-1.243	-1.378	-1.369	-1.367	-1.268	-1.281
38	-0.849	-0.875	-0.902	-1.145	-1.158	-1.195	-1.231	-1.317
39	-0.203	-0.135	-0.131	-0.170	-0.188	-0.198	-0.674	-0.418
40	-0.064	-0.146	-0.145	-0.177	-0.245	-0.199	-0.256	-0.298
41	-0.270	-0.437	-0.417	-0.358	-0.640	-0.312	-0.422	-0.347
42	-0.876	-0.812	-0.815	-1.032	-0.956	-1.073	-0.994	-1.120
43	-0.177	-0.069	-0.083	-0.628	-0.239	-0.669	-0.644	-0.941
44	-0.425	-0.262	-0.226	-0.191	-0.121	-0.210	-0.240	-0.284
45	-0.222	-0.278	-0.280	-0.204	-0.180	-0.218	-0.170	-0.347
46	-0.161	-0.278	-0.258	-0.133	-0.084	-0.119	-0.244	-0.306
47	0.076	-0.095	-0.062	-0.047	-0.085	-0.083	-0.089	-0.154

Table XIX. Surface Pressure Coefficients - Reynolds No. = 12 Million

Tap No.	α=-23.89 R=12.02 x 10^6 q=528.3 M=0.282	α=-20.20 R=12.04 x 10^6 q=526.9 M=0.282	α=-15.00 R=12.04 x 10^6 q=524.8 M=0.282	α=-10.18 R=12.05 x 10^6 q=524.1 M=0.282	α=-4.83 R=12.05 x 10^6 q=523.5 M=0.282	α=-4.06 R=12.01 x 10^6 q=526.2 M=0.283	α=0.04 R=12.06 x 10^6 q=522.8 M=0.282	α=4.90 R=11.97 x 10^6 q=524.1 M=0.282	α=10.06 R=11.97 x 10^6 q=524.7 M=0.282	α=15.11 R=11.98 x 10^6 q=524.8 M=0.282	α=19.95 R=11.91 x 10^6 q=520.7 M=0.281	α=23.92 R=11.91 x 10^6 q=521.4 M=0.281
2	-0.573	-0.600	-0.562	-0.578	-0.609	-1.520	-1.525	-1.508	-1.439	-1.332	-1.197	-1.038
3	-0.920	-0.915	-0.815	-0.734	-0.628	-0.774	-0.697	-0.525	-0.359	-0.183	-0.013	0.135
4	-1.087	-0.958	-0.763	-0.590	-0.392	-0.392	-0.273	-0.020	0.175	0.383	0.528	0.661
5	-0.608	-0.389	-0.128	0.109	0.323	0.381	0.488	0.697	0.831	0.930	0.992	1.015
8	0.496	0.670	0.838	0.938	1.001	1.008	1.017	0.974	0.891	0.782	0.591	0.419
7	1.005	0.952	0.838	0.690	0.503	0.422	0.300	-0.008	-0.259	-0.548	-0.836	-1.085
8	0.384	0.191	-0.068	-0.308	-0.562	-0.641	-0.772	-1.055	-1.270	-1.471	-1.572	-1.607
9	-0.158	-0.334	-0.544	-0.703	-0.862	-0.886	-0.950	-1.056	-1.116	-1.182	-1.186	-1.156
10	-0.400	-0.504	-0.641	-0.725	-0.792	-0.763	-0.775	-0.758	-0.758	-0.734	-0.667	-0.583
11	-1.118	-1.110	-1.103	-1.040	-0.948	-0.804	-0.751	-0.556	-0.488	-0.470	-0.335	-0.248
12	-0.295	-0.242	-0.251	-0.231	-0.221	-0.346	-0.507	-0.415	-0.303	-0.163	-0.271	-0.170
13	-0.351	-0.322	-0.246	-0.261	-0.254	-0.124	-0.208	-0.347	-0.232	-0.219	-0.183	-0.199
14	-0.249	-0.300	-0.311	-0.350	-0.412	-0.403	-0.368	-0.327	-0.155	-0.157	-0.185	-0.253
15	-0.374	-0.311	-0.278	-0.301	-0.349	-0.337	-0.453	-0.481	[illegible]	-0.766	-0.824	-0.855
16	-0.961	-1.009	-0.908	-0.867	-0.797	-0.949	-0.882	-0.736	-0.576	-0.422	-0.261	-0.122
17	-1.144	-1.079	-0.903	-0.764	-0.632	-0.839	-0.518	-0.309	-0.120	0.054	0.201	0.335
18	-0.871	-0.683	-0.451	-0.254	-0.080	-0.020	0.085	0.252	0.372	0.469	0.525	0.557
19	0.053	0.182	0.329	0.417	0.459	0.486	0.512	0.448	0.382	0.260	0.114	-0.037
20	0.603	0.545	0.432	0.295	0.129	0.081	-0.027	-0.291	-0.523	-0.784	-1.034	-1.230
21	0.227	0.062	-0.190	-0.399	-0.623	-0.714	-0.792	-1.029	-1.230	-1.415	-1.517	-1.553
22	-0.205	-0.371	-0.566	-0.731	-0.877	-0.869	-0.943	-1.005	-1.072	-1.130	-1.112	-1.068
23	-0.944	-1.044	-1.001	-1.011	-1.018	-1.326	-1.228	-1.202	-1.075	-0.951	-0.802	-0.652
26	-1.185	-1.198	-1.126	-1.083	-1.024	-1.048	-0.991	-0.874	-0.743	-0.656	-0.530	-0.408
27	-1.211	-1.126	-1.022	-0.927	-0.831	-0.826	-0.682	-0.659	-0.595	-0.509	-0.430	-0.427
28	[illegible]	-0.787	-0.713	-0.672	-0.652	-0.582	-0.549	-0.584	-0.648	-0.731	-0.797	-0.905
29	-0.296	-0.351	-0.460	-0.561	-0.663	-0.651	-0.674	-0.837	-1.008	-1.172	-1.304	-1.397
30	-0.214	-0.351	-0.539	-0.681	-0.840	-0.822	-0.887	-1.002	-1.132	-1.261	-1.290	-1.285
31	-0.332	-0.473	-0.613	-0.793	-0.912	-0.894	-0.895	-0.933	-0.986	-1.003	-0.948	-0.878
32	-0.521	-0.622	-0.682	-0.788	-0.889	-1.314	-1.315	-1.353	-1.294	-1.250	-1.163	-1.061
33	-0.762	-0.921	-0.976	-1.035	-1.115	-1.029	-1.020	-1.089	-1.095	-1.064	-1.056	-1.065
34	-1.236	-1.145	-1.186	-1.172	-1.174	-0.958	-0.871	-0.931	-1.045	-1.092	-1.146	-1.247
35	-1.065	-1.033	-1.073	-1.112	-1.139	-0.929	-0.872	-0.869	-0.946	-1.037	-1.001	-1.073
36	-0.570	-0.654	-0.794	-0.882	-0.953	-0.848	-0.817	-0.808	-0.802	-0.841	-0.737	-0.674
37	-0.269	-0.263	-0.263	-0.289	-0.317	-0.884	-0.976	-1.150	-1.130	-1.175	-1.141	-1.108
38	-0.257	-0.225	-0.273	-0.310	-0.378	-0.198	-0.186	-0.549	-0.521	-0.702	-0.886	-1.038
39	-0.275	-0.230	-0.302	-0.417	-0.522	-0.117	-0.099	-0.105	-0.093	-0.127	-0.205	-0.262
40	-0.990	-0.887	-0.824	-0.876	-0.830	-0.145	-0.108	-0.093	-0.133	-0.234	-0.248	-0.265
41	-0.856	-0.872	-0.971	-1.020	-1.016	-0.797	-0.728	-0.540	-0.510	-0.556	-0.402	-0.311
42	-0.304	-0.289	-0.277	-0.298	-0.330	-0.326	-0.557	-0.639	-0.778	-0.904	-0.937	-0.948
43	-0.323	-0.258	-0.288	-0.339	-0.400	-0.337	-0.338	-0.169	-0.136	-0.155	-0.139	-0.321
44	-0.251	-0.236	-0.250	-0.272	-0.286	-0.217	-0.297	-0.265	-0.188	-0.390	-0.313	-0.370
45	-0.224	-0.226	-0.232	-0.241	-0.261	-0.160	-0.176	-0.286	-0.321	-0.425	-0.418	-0.322
46	-1.070	-1.061	-1.069	-1.079	-1.020	[illegible]	-0.653	-0.332	-0.328	-0.414	-0.279	-0.245
47	-0.308	-0.279	-0.239	-0.195	-0.197	[illegible]	-0.263	-0.124	-0.156	-0.127	-0.119	-0.063

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13. ABSTRACT

To further the development of high-altitude tethered balloons, wind tunnel testing of a rigid model of a natural shape balloon was performed at Ames Aeronautical Laboratory of NASA. The rigid model tested represented a shape with top loading $F/p = 0$, superpressure parameter $\alpha = 0.9315$, and $\Sigma = 0.0315$. Aerodynamic data obtained in the Ames 12-foot pressure tunnel include lift, drag, pitching moment, and surface pressure distribution for the Reynolds number range of 450,000 to 12 million. Examination of the data, reduced by NASA, indicates that (1) stall occurs at a positive angle of attack less than 10 degrees, (2) an aerodynamic unstable trim point occurs between 5 and 15 degrees angle of attack, and (3) the drag at zero degrees angle of attack is greater than that of a sphere at the same Reynolds number.

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	ROLE	WT	ROLE	WT	ROLE	WT
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